Proceedings of the I·R·E

Journal of Communications and Electronic Engineering
(Including the WAVES AND ELECTRONS Section)

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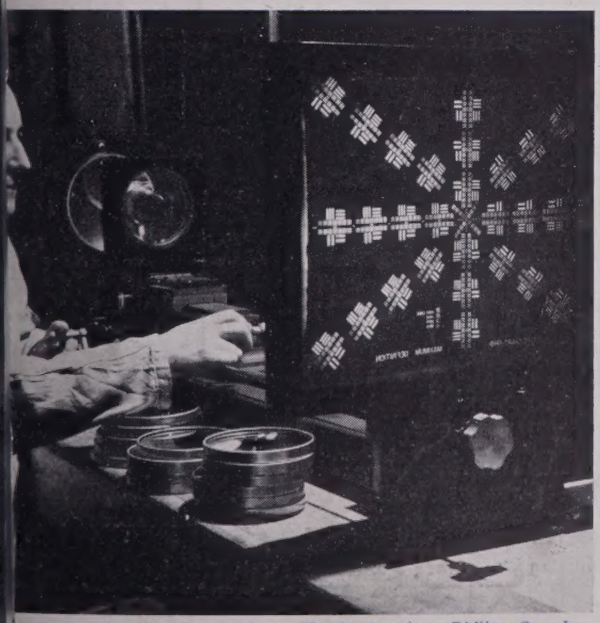

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Tropospheric Effects in Ionosphere-Supported Radio Transmission

Reliability of Ionospheric Height Determinations

Reflection-Method Antenna Impedance Measurement

Antenna Impedance Over Finite Ground Planes

Rectangular Waveguide Radiation

Filter-Type Traveling-Wave Amplifiers

Space-Charge Considerations in Test-Diode Design

The Synthesis of Electric Networks According to Prescribed Transient Conditions

Transient Response of Cathode Followers in Video Circuits

A Microwave Impedance Bridge

Closed- and Open-Ridge Waveguides

Broad-Band Dissipation Matching Structures for Microwaves

Wide-Band Waveguide Filter Analysis

Waves and Electrons Section

The Scintillation Counter

Standard Diode for Cathode Material Approval Tests

Testing Cathode Materials in Factory Production

Internal Series Resistance Measurement of a Capacitor under Surge Conditions

Experimental UHF Multiplex Broadcasting System

Pulse Modulation

Abstracts and References

TABLE OF CONTENTS FOLLOWS PAGE 32A

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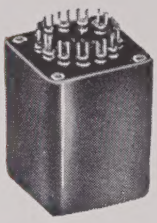

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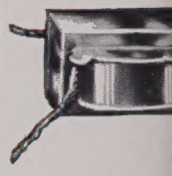

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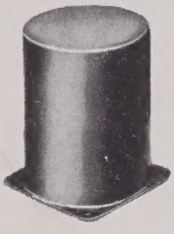

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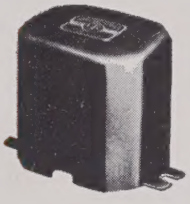

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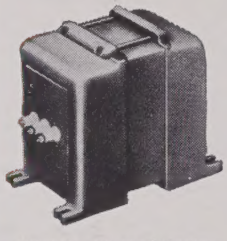

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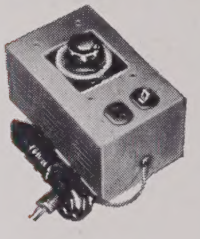

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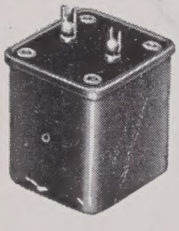

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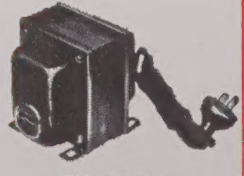

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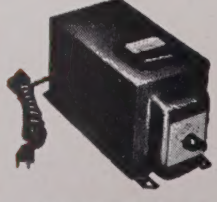

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PROCEEDINGS OF THE I.R.E.

Elmer W. Engstrom, Director, 1949 594
Clinton B. DeSoto 595
3342. Tropospheric Effects in Ionosphere-Supported Radio Transmission ..... Greenleaf W. Pickard and Harlan T. Stetson 596
3343. The Reliability of Ionospheric Height Determinations ..... Laurence A. Manning 599
3344. Antenna Impedance Measurement by Reflection Method ..... Edwin Istvánffy 604
3239. Correction to "Theory of the Superregenerative Amplifier" by Leon Riebman 608
3345. Measured Impedance of Vertical Antennas Over Finite Ground Planes ..... A. S. Meier and W. P. Summers 609
3346. Some Properties of Radiation from Rectangular Waveguides ..... J. T. Bolljahn 617
3347. A Note on Filter-Type Traveling-Wave Amplifiers ..... J. R. Pierce and Nelson Wax 622
2739. Correction to "Directional Couplers" by W. W. Mumford 625
3348. Note on Space-Charge Considerations in Test-Diode Design ..... Edward A. Coomes and James G. Buck 626
3349. The Synthesis of Electric Networks According to Prescribed Transient Conditions ..... Morton Nadler 627
3350. Transient Response of Cathode Followers in Video Circuits ..... B. Y. Mills 631
3351. A Microwave Impedance Bridge ..... M. Chodorow, E. L. Ginzton, and F. Kane 634
3352. Closed- and Open-Ridge Waveguide ..... T. G. Mihran 640
3353. Broad-Band Dissipative Matching Structures for Microwaves ..... Herbert J. Carlin 644
3354. Analysis of a Wide-Band Waveguide Filter ..... Seymour B. Cohn 651
Correspondence:
3355. "Notes on Digital Coding" ..... Marcel J. E. Golay 657
Contributors to PROCEEDINGS OF THE I.R.E. 657

INSTITUTE NEWS AND RADIO NOTES SECTION

Constitutional Amendment 660
Report of the Secretary—1948 661
Industrial Engineering Notes 666
Institute Committees—1949 667
Technical Committees, May 1, 1949–May 1, 1950 668
Institute Representatives in Colleges—1949 669
Institute Representatives on Other Bodies—1949 670
Books:
3356. "Elements of Electromagnetic Waves" by Lawrence A. Ware ..... Reviewed by L. J. Chu 670
3357. "Photofact Television Course" edited by B. V. K. French 670
3358. "Tables of Bessel Functions of Fractional Order," Volume II 670

WAVES AND ELECTRONS SECTION

3359. The Scintillation Counter ..... J. W. Coltman 671
3360. A Standard Diode for Electron-Tube Oxide-Coated Cathode-Core-Material Approval Tests ..... Robert L. McCormack 683
3361. Testing Cathode Materials in Factory Production ..... J. T. Acker 688
3362. A Method of Measurement of the Internal Series Resistance of a Capacitor Under Surge Conditions ..... Ben S. Melton 690
3363. Experimental Ultra-High-Frequency Multiplex Broadcasting System ..... A. G. Kandoian and A. M. Levine 694
3364. Pulse Modulation ..... E. M. Deloraine 702
Contributors to Waves and Electrons Section 706
3365. Abstracts and References 707
News—New Products 18A
Section Meetings 34A
Student Branch Meetings 38A
Membership 42A
Positions Open 50A
Positions Wanted 52A
Advertising Index 62A

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† Deceased.

Elmer W. Engstrom

DIRECTOR, 1949

Elmer W. Engstrom, vice-president in charge of research at the RCA Laboratories in Princeton, N. J., was born in Minneapolis, Minn., on August 25, 1901. After receiving the B.S. degree in electrical engineering from the University of Minnesota in 1923, he entered the employment of the General Electric Co., where he worked on transmitters, receivers, and sound motion pictures. He became an Associate Member of the IRE in 1925.

In 1930 Mr. Engstrom joined RCA, where he was successively employed in research positions of increasing responsibility, culminating in his being appointed to vice-presidency in 1945. Meanwhile, he transferred Member grade in the IRE in 1938, and was awarded th Fellow grade in 1940.

Mr. Engstrom has been a member of a number Institute Committees, including the Board of Editor Awards, and Nominations. A past president of th Princeton Chapter of Sigma Xi and current president the Industrial Research Institute, he is also chairman the Visiting Committee of the Navy Industrial Associ tion to the Naval Research Laboratory.

CLINTON B. DESOTO

1912–1949

On April 1, 1946, Clinton B. DeSoto (M'46–SM'49) assumed the duties of technical editor of the PROCEEDINGS OF THE I.R.E. Born in Ogilvie, Minnesota, in 1912, he attended the University of Wisconsin's School of Journalism.

Mr. DeSoto became a licensed radio amateur in 1926, and in 1930 he joined the American Radio Relay League headquarters staff as assistant to the secretary of the League, transferring to the editorial staff as assistant editor of *QST* in 1942. He became executive editor of *QST* in 1943 and editor in 1944.

The author of a number of books and magazine articles dealing with radio topics, Mr. DeSoto handled the revision and production of the 1943, 1944, and 1945 editions of "The Radio Amateur's Handbook." He was associated with the development of radio remote-control systems for military and amateur applications. From 1933 to 1936 he served as secretary of the Connecticut Valley Section of The Institute of Radio Engineers. He also did the publicity work for the 1948 and 1949 IRE National Conventions.

After his acceptance of the position of Technical Editor, Mr. DeSoto capably fulfilled the duties of his post, and added substantially to the clarity, arrangement, and promptness of issuance of the PROCEEDINGS OF THE I.R.E.

The following expressions concerning him were signed by his associates:

The death of Clinton B. DeSoto, a Senior Member of The Institute of Radio Engineers and Technical Editor of the PROCEEDINGS OF THE I.R.E., is a shock to me personally and to the entire Institute. During his three years as Technical Editor, his keen insight into the publication business made him a tower of strength on the headquarters' editorial staff; and his handling of publicity for our annual conventions was truly inspired. His passing leaves a vacancy in our staff which will be extremely difficult to fill, and a gap in our hearts that can never be filled.

STUART L. BAILEY
President

I have known Clint twenty years. He brought to the IRE a wonderful combination of professional editorial ability, knowledge of the printing arts, a keen sense of publicity values, and personal charm.

GEORGE W. BAILEY
Executive Secretary

Clinton DeSoto, scholar, gentleman, and capable administrator, leaves behind him a host of grieving friends. He combined literary skill, unusual ability to bring out the best in his associates, and unfailing willingness successfully to handle any task, no matter how troublesome or time-consuming. The IRE, whose Technical Editor he has been, has lost one of its finest representatives, and deeply regrets his untimely passing.

A. N. GOLDSMITH
Editor

Tropospheric Effects in Ionosphere-Supported Radio Transmission*

GREENLEAF W. PICKARD†, FELLOW, IRE AND HARLAN T. STETSON†, ASSOCIATE, IRE

Summary—The importance of meteorological effects in tropospheric transmission has been presented by the authors in previous papers. More extended observations in the 40- to 50-Mc band, recently analyzed, substantiate high correlations with temperature, atmospheric refraction, and wind direction.

Since ionospheric-supported transmissions must pass at least twice through the troposphere, investigations have been made for possible meteorological effects at frequencies from the broadcast band to 10 Mc and comparisons made with known tropospheric reception at frequencies in the 40 to 50 Mc band. Correlation coefficients as high as 0.8 ± 0.1 are shown.

Reception from WBBM, Chicago, 850 miles distant, based on 3 years data, show a direct correlation with surface refraction and with atmospheric temperature changes. Night fields rise from a minimum one day before a temperature rise equal to 10°F to a maximum on the day such temperature change occurs. Similarly, a drop in field occurs one day prior to an equal temperature fall.

Studies of reception at Needham of WWV, 5 Mc (Beltsville, Md.) 373 miles distant, show similar correlations as those determined for the broadcast band. Furthermore, night fields of WWV, 5 Mc tend to a maximum one day preceding a prevailing SE wind directed broadside to the transmission path. Little correlation was found with NE winds directed along the path. Variations in field intensities, range from 15 to 30 per cent of mean fields dependent upon meteorological conditions at the receiving end. Such variations may be attributed to atmospheric bending, reflection transmissions due to changing lapse rate at the lower atmospheric levels, and possibly to as yet undetermined troposphere-ionosphere relations.

FOR THE PAST DECADE, interest in tropospheric effects on radio transmission has been almost entirely centered on the very high frequencies, largely because of the wartime importance of radar. But inasmuch as all ionosphere-supported transmission must pass at least twice through the troposphere, all portions of the radio spectrum must, to some extent, at least, be affected by happenings in the lower atmosphere.

In one respect only is there a fundamental difference with respect to frequency; the duct transmission so often observed at vhf is absent at the lower radio frequencies, since these are beyond cutoff for any duct dimension possible in the troposphere. In all other respects, tropospheric effects are not dependent on frequency, save only that reflection from discontinuities, such as temperature or humidity inversions, and at interfaces of air masses of different refractive index is greater at the lower the frequency. And the changes in wave bending due to varying refractive lapse rate may be expected to be the same at all presently used frequencies.

It might be expected that correlations of radio trans mission with tropospheric changes at any one point o the transmission path would be most prominent on rela tively short distance transmission, for the reason tha only on such paths would the atmosphere involved b in any sense homogeneous. This has been confirmed b an examination of 3 years continuous field strength re cording at the MIT Cosmic Terrestrial Research Labo ratory at Needham, Mass., from station XEWW a Mexico City, Mexico, operating at 9.5 Mc and 230 miles distant. This is a two-hop path, and transmissio must, therefore, pass four times through the tropo sphere, in three widely separated areas; obviously tropo spheric conditions would, in general, be different in thes areas, so it was not unexpected that analysis of the fiel data showed no definite correlation with Bosto weather elements.

In 1928 one of the present authors[1] examined the rela tion between night fields at Newton Center, Mass., fro broadcast station WBBM at Chicago, then operating a 1330 kc and 850 miles distant, and also the night field at Pasadena, Calif., from broadcast station KPO at Sa Francisco, Calif., operating at 680 kc and 343 miles dis tant, with surface temperature and barometric pressur at different points along the transmission paths. Th highest correlation found was with surface temperatur at the receiving point, and the relation found was direct and not inverse as Austin[2,3] had previously found fo his day fields.

In 1933 Colwell[4] found the field at Morgantown W. Va., from broadcast station KDKA at Pittsburgh Pa., 60 miles distant, showed marked correlation wit surface pressure changes, and particularly with the rela tive location of high- and low-pressure areas to th transmission path.

In this early work there was little attempt to sugges a mechanism by which tropospheric changes might af fect radio transmission. But in 1937 Watt, Wilkins, an Bowen in England[5] and Friend and Colwell in this coun try[6] independently observed and reported reflection

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† Cosmic Terrestrial Research Laboratory, Massachusetts Institute of Technology, Needham, Mass.

[1] G. W. Pickard, "Some correlations of radio reception with a mospheric temperature and pressure," PROC. I.R.E., vol. 16, pp. 765 773; June, 1928.

[2] L. W. Austin, "Field intensity measurements in Washington o the Radio Corporation stations at New Brunswick and Tuckerto New Jersey," PROC. I.R.E., vol. 12, pp. 681–693; December, 192

[3] L. W. Austin and I. J. Wymore, "Radio signal strength an temperature," PROC. I.R.E., vol. 14, pp. 781–785; December, 192

[4] R. C. Colwell, "Cyclones, anticyclones, and the Kennelly Heaviside layer," PROC. I.R.E., vol. 21, pp. 721–725; May, 1933.

[5] R. A. W. Watt, A. F. Wilkins, and E. G. Bowen, "The retur of radio waves from the middle atmosphere," *Proc. Roy. Soc.*, se A, vol. 161, pp. 181–196; July, 1937.

[6] A. W. Friend and R. C. Colwell, "Measuring the reflecting r gions in the troposphere," PROC. I.R.E., vol. 25, pp. 1531–1541; D cember, 1937.

from layers between 1 and 12 km in height, with occasional echoes from over 15 km. Friend and Colwell suggested that these tropospheric reflections might explain Colwell's earlier observations.

In this present paper, the authors have re-examined WBBM Chicago to Boston transmission with respect to Boston weather elements, and in addition have analyzed over three years each of Needham recorded fields from WWV 5 Mc, XEWW 9.5 Mc, WWV 10 Mc, and W2XMN at 44.1 Mc for correlation with tropospheric changes. They had previously[7] established certain tropospheric correlations with the W2XMN field at Needham with two years of recording: here another year of data has been added. For the reason that the transmissions other than W2XMN generally contained day-to-day and even hour-to-hour ionosphere-controlled changes of much greater magnitude than the tropospheric amplitudes, the analysis used throughout was purely statistical. In this form of analysis, some sharply defined tropospheric event, such, for example, as a large temperature change, is taken as an epoch, and received fields are repeatedly summed up around a series of such epochs. Field changes which are not related to the epoch distribute randomly around the epoch and tend to cancel out, such cancellations being the more complete the longer the series, while related field changes continually add up to maxima and minima.

A statistical examination of 1945, 1946, and 1947 values of critical frequencies has been made with $f^{\circ}E$ and $f^{\circ}F_2$ distributions around tropospheric events, and no definite correlation became apparent. However, relation of troposphere and ionosphere cannot be ruled out; Mihran[8] has recently shown an apparent correlation.

Fig. 1 shows the relation of a purely tropospheric radio transmission, W2XMN at Alpine, N. J., operating at 44.1 Mc as received at Needham, Mass., 167 miles away, to Boston; mean temperature changes taken as epochs. It will be noted that this figure contains an element of prediction as field maxima and minima precede by 1 day the Boston temperature changes taken as epochs. The correlation between W2XMN fields and Boston temperatures is best seen by the dotted line showing Boston temperature distribution around Boston temperature rise (moved 1 day to the left) against the full-line curve for W2XMN.

In the absence of tropospheric soundings, surface refraction is our only available measure of refractive lapse rate, which determines the bending of radio wave fronts. In order to compare radio transmission with tropospheric reflections from inversions and interfaces, it is, at present, necessary to do this indirectly; that is, to compare some surface event which is related to inversions. One such surface event is a prevailing wind from the ocean, particularly during the summer months. As the transmission path from Alpine to Needham runs NE-SW, a SE wind will reach the path most directly.

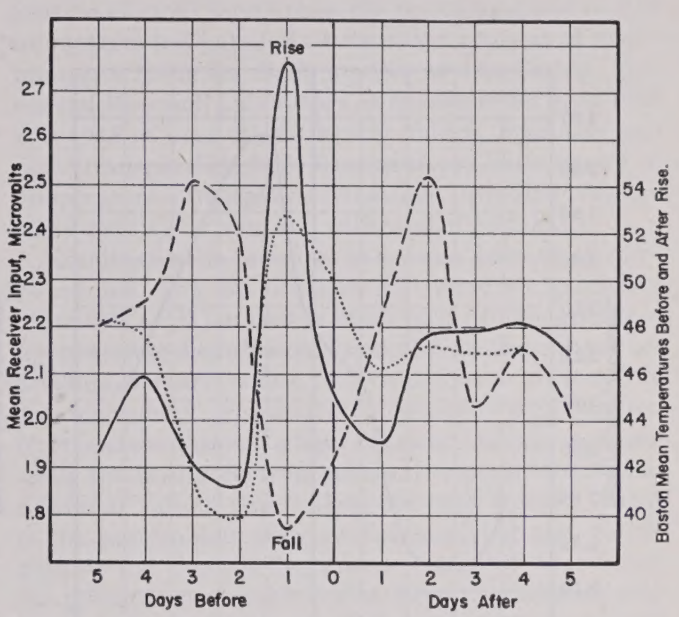

Fig. 1—Distribution of W2XMN fields around Boston mean temperature rise and fall of ≧10°F. 80 cases, 1945 to 1948.

In Fig. 2 are shown in full-line W2XMN fields against SE prevailing winds at Boston as epoch. Despite the imperfection of SE winds as an index of inversions, a clear relation with an amplitude of 15 per cent is shown.

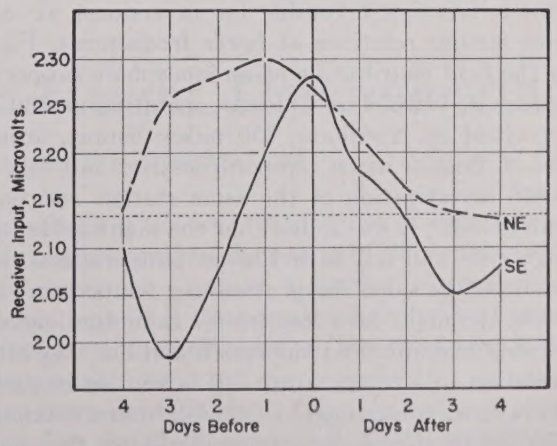

Fig. 2—Distribution of W2XMN fields around Boston SE and NE winds. Winter and summer, 1945 to 1948.

A less definite correlation with NE winds is shown in broken line. This figure is based upon all SE and NE winds, both summer and winter, with 61 cases of SE wind and 83 cases of NE wind.

[7] G. W. Pickard and H. T. Stetson, "A study of tropospheric reception at 42.8 Mc and meteorological conditions," PROC. I.R.E., vol. 35, pp. 1445–1450; December, 1947.

[8] T. G. Mihran, "A note on a new ionospheric-meteorological correlation," PROC. I.R.E., vol. 36, pp. 1093–1096; September, 1948.

In Fig. 3, based upon 23 cases, is shown the distribution of W2XMN fields around SE winds at Boston, during June, July, August, and September. Here the maximum is reached 1 day after the SE wind's advent, and the amplitude has increased to 34 per cent, from the 15 per cent of the preceding figure.

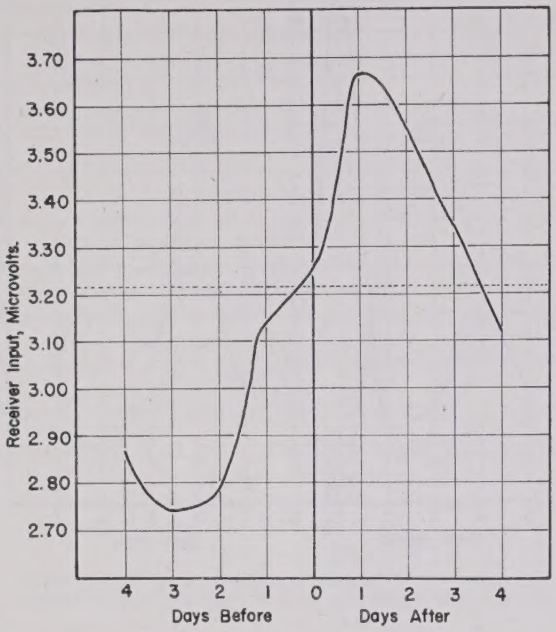

Fig. 3—Distribution of W2XMN fields around Boston SE wind, June, July, August, and September only.

Having shown that a purely tropospheric transmission, at a frequency too low for duct transmission, is highly related to tropospheric changes in temperature and wind direction favorable for inversions, we next examine similar relations at lower frequencies. Fig. 4 shows the field distribution of an ionosphere-supported transmission, WBBM at Chicago, operating at 780 kc, and received at Needham, 850 miles distant, around epochs of Boston mean temperature rise and fall. In the 1928 investigation of the same station and path, then at 1330 kc, it was found that the night fields from Chicago rose and fell with Boston temperatures; this figure shows the same thing. Around a temperature rise as epoch, the night field rose from a minimum one day before to a maximum on the epoch and one day after. The relation to a temperature fall is seen to be rather closely inverse, consisting of a field fall from a maximum one day before to a minimum one day after the epoch. And from four days before to five days after the epoch, the curves run inversely. A portion of the temperature distribution around the temperature rise is shown in dotted line; the correlation here is $r=0.8\pm0.07$ or a ratio of correlation coefficient to probable error of over 11.

We shall next examine transmission from WWV's transmitter at Beltsville, Md., 373 miles distant from Needham. Owing to the shortness of the path from Beltsville to Needham, the transmission passes through the troposphere at a fairly high angle, which would not favor reflections; nevertheless, a clear correlation is evident for night fields.

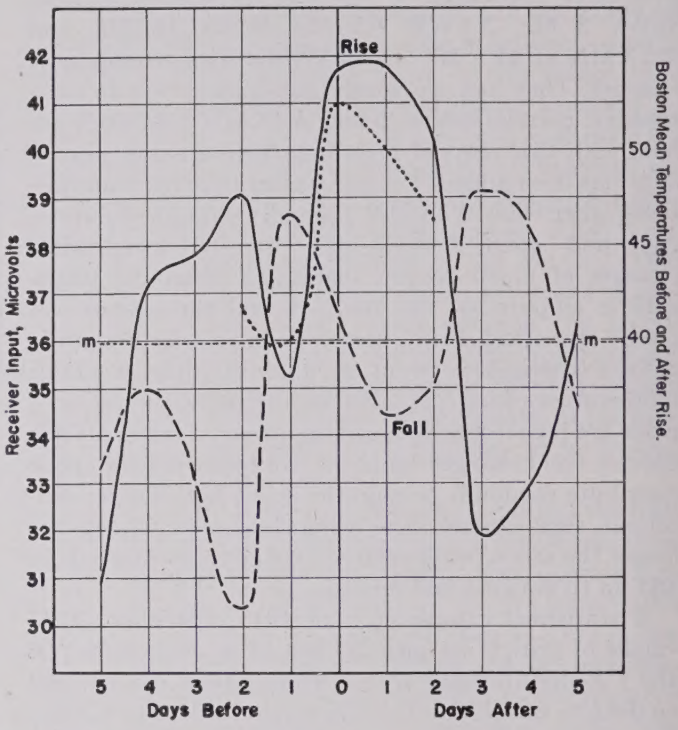

Fig. 4—Distribution of WBBM fields around Boston mean temperature rise and fall of ≧10°F. 80 and 72 cases, respectively, 1945 to 1948.

In Fig. 5 is shown the distribution of WWV 5-Mc night fields at Needham with respect to Boston temperature rise and fall. It will be seen that the curves run inversely throughout, and also that the relation to Boston

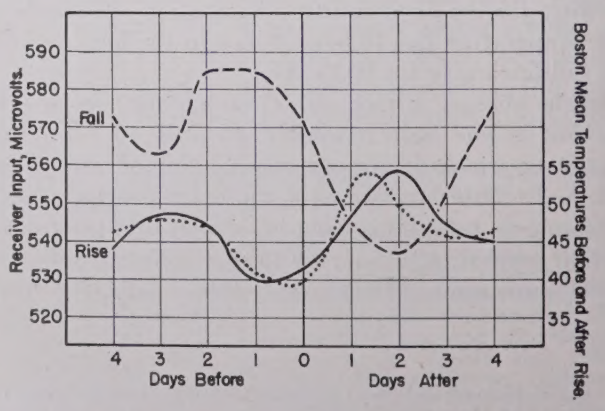

Fig. 5—Boston mean temperature rise and fall of ≧10°F as epoch: WWV-5 21-03 E.S.T., 90 and 80 cases respectively, 1945 to 1948.

temperature is inverse, as has already been shown for WBBM night fields at broadcast frequencies. Again for comparison is shown in dotted line the distribution of Boston temperatures around rises; this has been moved one day to the right, as WWV 5-Mc fields lag temperature by one day. The correlation between the dotted and full line curves is $r=0.8\pm0.1$, or a ratio of correlation coefficient to probable error of 8.

In Fig. 6 is shown the distribution of WWV 5-Mc

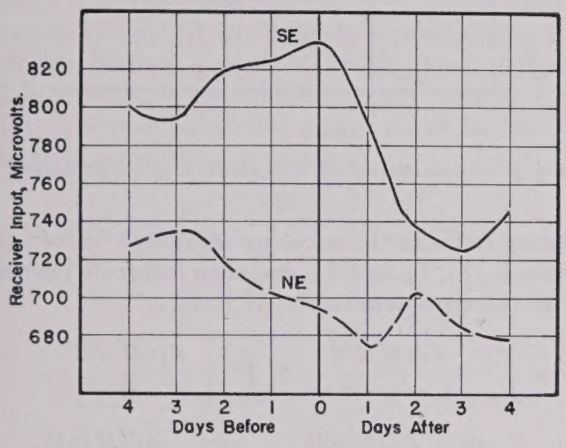

Fig. 6—Distribution of WWV–5 night fields around Boston SE and NE winds.

night fields with respect to SE and NE winds. The full-line curve is for SE winds, and reaches a maximum on the epoch day, whereas the NE wind distribution shows little correlation. Again, in view of the unfavorable angle which this transmission makes with the nearly horizontal reflecting layers, it is perhaps surprising that any correlation should be shown.

In conclusion, it may be stated that this investigation of the effects of meteorological changes upon the propagation of radio waves from the broadcast band to FM frequencies has entailed an extended analysis of measurements made for basic studies at the Cosmic Terrestrial Research Laboratory at Needham between 1945 and 1948 of over 30,000 hourly values. Both day and night transmissions have been analyzed with respect to temperature, atmospheric refraction, including pressure and humidity factors, and with wind direction.

Examination in detail of this large amount of computational work has revealed that there are variations of from 15 to 30 per cent in mean-field values dependent upon meteorological conditions. There have been individual instances where field variations as great as 2 to 1 in ionospheric-propagated transmission have resulted from meteorological factors affecting the waves necessarily traversing the troposphere. Investigations of conditions at various points along the path indicate that it is the atmospheric state at the receiving end, rather than at the transmitting end or midpoint, that shows the greatest correspondence between transmission conditions and the meteorological elements at the earth's surface. It is apparent that lack of uniformity in the lower atmosphere introduces variable refraction and reflection from inversions and air-mass interfaces. This causes significant effects in communication at relatively low frequencies.

The Reliability of Ionospheric Height Determinations*

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Summary—**A study is made of the uncertainties existing in determinations of electron distribution based on virtual height data. The effect of an assumed distribution in the valley between two layers upon the necessary upper-layer form is investigated, and a method for evaluating the maximum error in height determination is given.**

Introduction

IN A PREVIOUS paper[1] the writer has shown that analysis of ionospheric virtual height versus frequency records, by a process of integral transformation, will yield the true distribution of electrons in the upper atmosphere. In the course of that analysis it was found necessary to make a number of idealizing approximations. It is the purpose of the present paper to investigate the significance of the most restrictive of these assumptions.

It was assumed that:

(a) The distribution function $Z(M)$, specifying the height at which an electron density M is found, is single-valued. This condition is violated by an ionosphere of more than one layer.

(b) The ionosphere is lossless, or that the electron collision frequency is zero. In the E layer the assumption is not upheld.

(c) Geometrical optics is valid. At the top of the path the assumption is invalid.

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† Stanford University, Stanford, Calif.

[1] L. A. Manning, "The determination of ionospheric electron distribution," PROC. I.R.E., vol. 35, pp. 1203–1208; November, 1947.

(d) The earth's magnetic field does not affect propagation.

Assumption (b), (c), and (d) have been treated by Rydbeck.[2,3] Assumption (a) is of greater practical importance, and will be considered forthwith.

Basic Distribution Analysis

As in the previous paper, the abbreviation $M=KN$ will be used for electron density. It is proportional to the true electron density N, but has units of squared frequency. The function $M(z)$ specifies the density at hieght z, while the inverse function $Z(M)=M^{-1}(z)$ gives the heights at which the density M is to be found. In terms of the distribution function $M(z)$ it is possible to write the virtual height versus frequency integral expressing the experimentally measured time delays as

$$z_v(f) = \int_0^{z_{max}=M^{-1}(f^2)} \frac{dz}{(1-M/f^2)^{1/2}} \tag{1}$$

where f is frequency. When only one layer maximum is present, $M(z)$ is monotonically increasing, and the inverse function $Z(M)$ is single-valued. Then it is possible to write (1) in the equivalent form:

$$z_v(f) = \int_0^{f^2} \frac{Z'(M)dM}{(1-M/f^2)^{1/2}}. \tag{2}$$

It was shown that, in cases in which the inversion of $M(z)$ is valid, the integral may also be inverted; the distribution function is then given in terms of the experimentally determined virtual height versus frequency function by

$$Z_T(f_v) = \frac{2}{\pi}\int_0^{f_v} \frac{z_v(f)df}{(f_v^2-f^2)^{1/2}} \tag{3}$$

in which $Z_T(f_v)$ is the true height of penetration of a wave of vertical-incidence frequency f_v.

Correction for Second Layer

Virtual-height data is not sufficient to determine the electron distribution at heights beyond the first layer maximum. Nevertheless, the integral of (3) can still be evaluated at frequencies higher than the first-layer critical frequency. From physical considerations it was indicated in the first paper that, when the frequency f_v is much greater than a lower critical frequency, the error of assuming the representation of (2) to be possible must approach zero. The error which will actually result from applying (3) when several layers exist will now be investigated.

In Fig. 1 is shown an electron-distribution curve representing a lower layer of critical frequency f_0; it shields a valley at heights between z_0 and z_2. At heights greater than z_2 the electron density rises again to a higher maximum. Note that $Z(M)$ is triple-valued when $f_1^2<M<f_0^2$. In order to apply (2) when $f>f_0$, it is

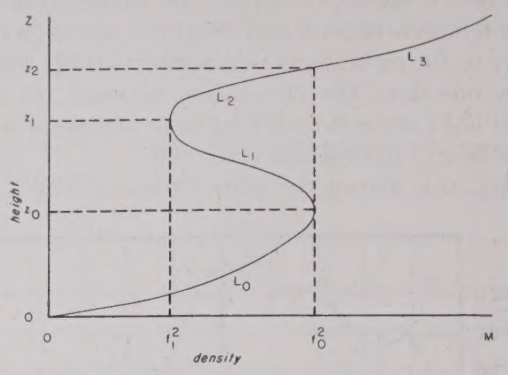

Fig. 1—A multiple-valued ionospheric height distribution.

necessary to break the curve up into single-valued components L_0, L_1, L_2, and L_3, and then integrate over each part of the path separately. If $f>f_0$,

$$z_v(f) = \int_0^{f_0^2} \frac{Z_0'(M)dM}{(1-M/f^2)^{1/2}} + \int_{f_1^2}^{f_0^2} \frac{Z_1'(M)dM}{(1-M/f^2)^{1/2}} + \int_{f_1^2}^{f_0} \frac{Z_2'(M)dM}{(1-M/f^2)^{1/2}} + \int_{f_0^2}^{f^2} \frac{Z_3'(M)dM}{(1-M/f^2)^{1/2}} \tag{4}$$

where $Z_1(M)$ is the distribution over the part of the curve L_1, and is measured from the height z_1 downwards. Distribution $Z_2(M)$ is also measured from the valley minimum. The two inner integrals represent the retardation in the valley. The form of (4) shows that, for $f>f_0$, the retardation is exactly the same as would be obtained from a new distribution $Z_b(M)$ defined by

$$Z_b(M) = Z_0(M) + Z_1(M) + Z_2(M) + Z_3(M), \tag{5}$$

inasmuch as application of (2) to (5) yields just (4). When $f_1<f<f_0$, the virtual height resulting from $Z_b(M)$ does not correspond to the experimental retardation, which is dependent on $Z_0(M)$ alone. Since Z_0, Z_1, Z_2, and Z_3 are all defined in such a way as to be monotonically increasing and single-valued, $Z_b(M)$ is also. Fig. 2 shows the form of the new distribution.

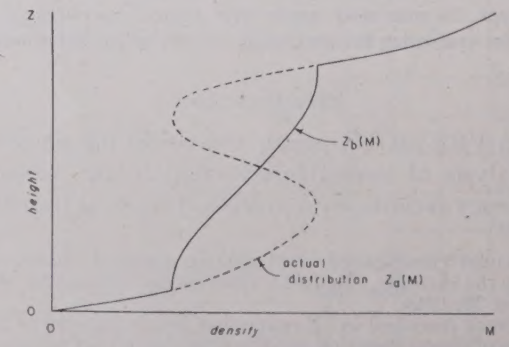

Fig. 2—A single-valued ionization distribution giving identical retardation at high frequencies as the actual distribution.

[2] O. E. H. Rydbeck, "On the propagation of radio waves," *Chalmers Tek*, Hogskol, Handl. No. 34, 158 pp.; 1944.

[3] O. E. H. Rydbeck, "Theoretical survey of the possibility of determining the distribution of free electrons in the upper atmosphere," *Chalmers Tek*, Hogskol, Handl. No. 3, 74 pp.; 1942.

The new distribution gives the same retardation as the old distribution when $f>f_0$, but since it is single-valued the representation of (2), and the resultant inversion of (3), are possible. The true height corresponding to $z_v(Z_b)$ is uniquely Z_b. Since Z_b is the same as the original distribution for $z>z_2$, analysis of $z_v(Z_b)$ leads to the correct true height Z_a when $z>z_2$. To find the true distribution Z_a for $0<z<z_0$, the experimental virtual height $z_v=z_v(Z_0)$ is correct.

When $f>f_0$, the experimental $z_v(Z_a)$ is equal to $z_v(Z_b)$. When $f<f_0$, the experimental z_v is $z_v(Z_0)$ while the virtual height $z_v(Z_b)$ which leads to the correct *upper-layer* distribution is $z_v(Z_0+Z_1+Z_2)$. Their difference, $z_v(Z_1+Z_2)=\Delta z_v$, is the addition which must be applied to the experimental virtual-height curve before it will give the true distribution for $z>z_2$.

$$\Delta z_v = \int_{f_1^2}^{f^2} \frac{Z_1'(M)+Z_2'(M)}{(1-M/f^2)^{1/2}}\,dM \equiv \int_{z_1}^{M_1^{-1}(f^2)} \frac{dz}{(1-M_1/f^2)^{1/2}} + \int_{z_1}^{M_2^{-1}(f^2)} \frac{dz}{(1-M_2/f^2)^{1/2}}. \tag{6}$$

Error arises in computing the true height of the upper layer if the experimental data are used, because the virtual height in the region $f_1<f<f_0$ is too small by the amount Δz_v. The magnitude of the height error can be ascertained by substituting Δz_v of (6) in (3).

$$\Delta Z_T(f_v) = \frac{2}{\pi}\int_{f_1}^{f_0} \frac{\Delta z_v(f)df}{(f_v^2-f^2)^{1/2}}. \tag{7}$$

The true height of the layer is always greater than that computed directly from the experimental data by the amount ΔZ_T.

Nature of the Single-Valued Distribution

When the experimental data are analyzed by applying (3) directly, a single-valued distribution is obtained which is lower than the true distribution by the error height ΔZ_T. Fig. 5 shows such a distribution. Now, we wish to show that the single-valued distribution thus obtained is consistent with the experimental virtual-height curve, and that it is *mathematically* a correct solution to the true-height problem.

If $v(f)$ is the component of virtual height resulting from passage of the wave through the valley of the multiple-valued distribution, and $\delta Z(M)$ is the difference between the heights of the single- and multiple-valued curves for $M>f_0^2$, the condition that both curves give the same total virtual height is

$$\int_{f_0^2}^{f^2} \frac{-\delta Z'(M)dM}{(1-M/f^2)^{1/2}} = v(f). \tag{8}$$

Reference to (2) shows that the integral on the left is the increased virtual height the single-valued distribution must give, for heights above $M=f_0^2$, in order to compensate for its lack of valley retardation. The valley retardation $v(f)$ is given in terms of the valley-height distribution $V(M)=Z_1(M)+Z_2(M)$ by

$$v(f) = \int_{f_1^2}^{f_0^2} \frac{V'(M)dM}{(1-M/f^2)^{1/2}}. \tag{9}$$

By taking $\delta Z(M)$ and $V'(f)$ to be zero for M less than f_0^2 and f_1^2, respectively, the lower limits in the integrals of (8) and (9) may be made zero. Then, application of the inversion of (3) demonstrates that

$$\delta Z(f_v) = h - \frac{2}{\pi}\int_0^{f_v} \frac{v(f)df}{(f_v^2-f^2)^{1/2}} \tag{10}$$

where h is the valley width. The above equation gives the height difference between a multiple-valued distribution and a single-valued distribution having the same virtual height. Equation (7) give the relation between a multiple-valued distribution and the single-valued distribution obtained by analyzing directly the virtual height curve corresponding to the multiple-valued distribution. If we can show that $\delta Z(f_v)=\Delta Z_T(f_v)$, we will have shown that the true height obtained by applying (3) to the experimental data is always consistent with the experimental virtual height. We will also have shown that (6) and (7) can be used to find new true-height curves containing arbitrarily assumed valley distributions and giving the correct virtual height, because the height correction $\Delta Z_T(f_v)$ being added to the experimentally determined true height will exactly compensate for the assumed valley retardation by virtue of (8) through (10).

To show that (7) and (10) are identical, it is first necessary to put (6) in (7), and (9) in (10). Remember that $V(M)=Z_1(M)+Z_2(M)$ is the valley distribution. Thus, letting $f^2=g$,

$$\Delta Z_T(g_v) = \frac{1}{\pi}\int_0^{g_0}\int_0^{g} \frac{V'(M)dMdg}{(g-M)^{1/2}(g_v-g)^{1/2}} \tag{11}$$

and

$$\delta Z(g_v) = h - \frac{1}{\pi}\int_{g_0}^{g_v}\int_0^{g_0} \frac{V'(M)dMdg}{(g-M)^{1/2}(g_v-g)^{1/2}}. \tag{12}$$

These integrals can be shown to be equal by changing the order of integration, and noting that the valley width $h=\int_0^{g_0}V'(M)dM$. Both integrals then become

$$\Delta Z_T(g_v) = \delta Z(g_v) = \frac{2}{\pi}\int_0^{g_0} V'(M)\sin^{-1}\left(\frac{g_0-M}{g_v-M}\right)^{1/2}dM, \tag{13}$$

and the mathematical correctness of the directly obtained solution of the true height problem is demonstrated despite the presence of more than one layer maximum.

Effect of Assumed Valley Distributions

From ionospheric-sounding data it is physically impossible to determine the distribution of electrons in the valley of the true-height curve. Since the valley distribution is needed to evaluate the error heights of (6) and (7), or their equivalent, (13), it is not possible to correct the upper-layer distribution exactly. What can be done is to make a number of assumptions as to the valley distribution, and then consider the resulting corrections as first approximations to the true corrections, or as limits to the error of the analysis.

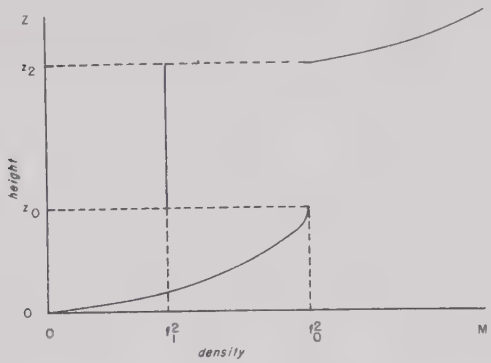

Fig. 3—An assumed constant-density valley distribution.

The simplest assumption about the valley is that it is of constant electron density $M=f_1^2$, as in Fig. 3. Then the virtual-height correction of (6) becomes

$$\Delta z_v = \int_{z_0}^{z_2} \frac{dz}{(1-f_1^2/f^2)^{1/2}} = \frac{h}{(1-f_1^2/f^2)^{1/2}}$$

where $z_2-z_0=h$ is the valley width. The error height ΔZ_T of (7) is now

$$\Delta Z_T = \frac{2}{\pi}\int_{f_1}^{f_0} \frac{h}{(1-f_1^2/f_0^2)^{1/2}} \cdot \frac{df}{(f_v^2-f^2)^{1/2}} = \frac{2}{\pi} h \sin^{-1}\left(\frac{f_0^2-f_1^2}{f_v^2-f_1^2}\right)^{1/2} \tag{14}$$

when $f_v>f_0$. If $f_v<f_0$, $\Delta Z_T=0$. Note that when at the critical frequency, with $f_v=f_0$, the true-height correction is equal to the width of the valley. For higher frequencies the error decreases, and approaches zero when f_v/f_0 approaches infinity.

The true-height curve obtained by direct application of (3) to the experimental records does not have discontinuous jumps in height at a critical frequency. The discontinuity in the true-height curve which actually exists across the valley must be obtained by adding the discontinuous correction factor; since the correction factor is zero for $f<f_0$, and invariably equal to h at $f=f_0$, application of (7) corrects for the inability of the single-valued analysis to cope with a multiple-valued situation.

The result of (8) is useful mainly in establishing a limit to the error in neglecting the valley density. If it is assumed that there are no electrons in the valley, $f_1=0$, and $\Delta Z_T=(2/\pi)h \arcsin(f_0/f_v)$. If h is assumed to be larger than the actual valley width, the error height of this assumption will be larger than the true correction, and a bound is placed on the inaccuracy of the upper-layer height determination. In curve (a) of Fig. 4 is plotted the error height in percentage of the valley

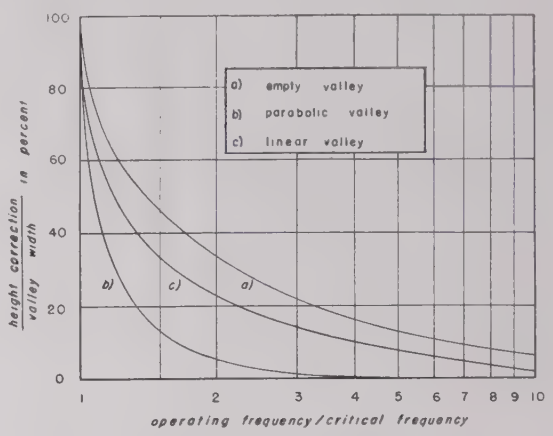

Fig. 4—Height corrections computed for three assumed valley distributions.

width, as a function of the extent by which the frequency exceeds the lower critical frequency. In Fig. 5 are shown the upper-layer electron distributions which would result in a typical case from assuming an unionized valley of various widths. The record used is that of Fig. 9 of the previous paper.

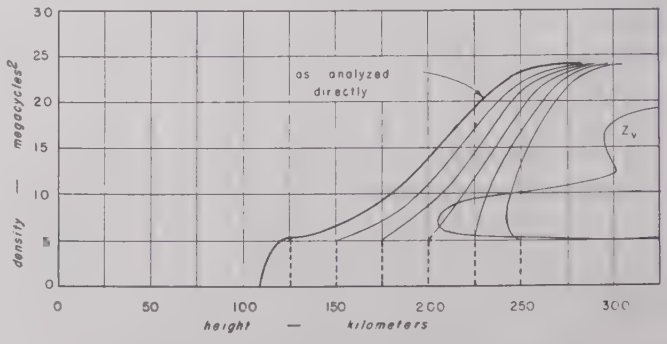

Fig. 5—An example of an electron distribution corrected for assumed empty valleys of various widths.

Note that a valley width of greater than about 110 km is impossible physically in Fig. 5, since the $M(z)$ curve would become multiple-valued. A further restriction on the width of the valley may be obtained by noting that the computed true height must be less than the virtual height, as witness (1). The true height can only exceed the virtual height in the physically impossible case in which $M(z)$ is multiple-valued, and more than one electron density is ascribed to a given height. As applied to Fig. 5, this condition demands that the val-

ley width be less than about 77 km. The first condition should serve as well, if it were possible to get the form of the curves with sufficient accuracy when M is but slightly greater than f_0^2. If we now assume the largest possible valley width of 77 km, and then assume the least possible number of electrons in the valley, the error in the computed true height of the F-layer maximum is only 25 km. On the basis of other assumptions as to valley distribution, the true height error at the F-layer maximum would be less.

It is rather likely that the lower-layer ionization suddenly drops to zero beyond the height z_0. A more reasonable assumption is that the ionization drops off as the tail of a Chapman region; as an approximation valid near z_0, we shall assume the density to drop off parabolically. Let the parabola be $M=f_0^2[1-(z/h)^2]$, so that in a width h of valley the ionization density decreases from f_0^2 to zero. Then,

$$\Delta z_v = \int_h^{h(1-f^2/f_0^2)^{1/2}} \frac{dz}{\{1-f_0^2[1-(z/h)^2]/f^2\}^{1/2}}$$

$$= -\frac{hf}{2f_0}\ln\frac{f_0-f}{f_0+f},$$

and the error height is

$$\Delta Z = -\frac{2}{\pi}\int_0^{f_0}\frac{hf}{2f_0}\frac{\ln\dfrac{f_0-f}{f_0+f}}{(f_v^2-f^2)^{1/2}}df.$$

Integrated by parts, the error height becomes

$$\Delta Z = \frac{2}{\pi}h\sin^{-1}\frac{1}{r} - \frac{h}{\pi}(r^2-1)^{1/2}\ln\frac{r^2+1}{r^2-1} \qquad (15)$$

where $r=f_v/f_0$. Equation (15) is plotted as curve (b) in Fig. 4.

One other easily computed valley distribution is that for which the density varies linearly from zero to f_0^2 in a width h. Then $\Delta Z_v=2h\,f^2/f_0^2$, and

$$\Delta Z = \frac{2}{\pi}h\left\{r^2\sin^{-1}\frac{1}{r} - (r^2-1)^{1/2}\right\} \qquad (16)$$

where as above $r=f_v/f_0$. Equation (16) is also in Fig. 4 as curve (c).

If it is desired, the valley may be divided into a number of regions. The first region might be parabolic and of width h_p, the second of constant density zero and width h_0, while the last section might be linear of width h_l. The total correction ΔZ_T is then the sum of those found separately for all the sections of the valley.

The true-height corrections which have been computed provide a means of establishing limits to the height errors. Whenever a valley distribution is assumed, and a corrected true-height curve obtained, analysis of this distribution function by the application of (1) will give the experimental virtual-height curve. Thus, merely on analytic grounds, the uncorrected true-height curve is as good a solution to the problem presented by the experimental virtual-height curve as is a corrected curve embodying a valley. The argument in favor of assuming a valley distribution must be based either on physical reasoning as to probable layer shapes, or upon considerations of continuity between records obtained at different times of day.

It seems worth noting that the present method of analysis obtains the maximum possible amount of information from the experimental curves. All uncertainties in the distribution are effects of the physical situation and so penetrate such approximate methods of true-height analysis as Booker and Seaton's parabolic layer-matching process.[4]

Conclusion

An analysis of virtual-height records possessing critical frequencies invariably involves ambiguity with respect to that portion of the electron distribution beyond the first layer maximum. Direct integral analysis of the experimental virtual-height curves determines a distribution having an inflection in height versus density at the density corresponding to the critical frequency. The distribution thus found shows no valley between separate layers, and is consistent with the experimental virtual-height curves. For physical reasons, one may believe that several separate layers actually exist. It is then possible to find a true-height correction which makes the computed true height include the postulated valley, and yet be consistent with the virtual-height data. A limit on the width of an assumed valley is imposed when it is found that the corrected true-height curve is multiple-valued in electron density. By assuming the largest valley which still permits interpretation with a physically realizable distribution, a limit is found to the error in determination of upper-layer true height. The uncertainty found applies to any method of true-height analysis from virtual-height data.

[4] H.G. Booker and S. L. Seaton, "Relation between actual and virtual ionospheric height," *Phys. Rev.*, vol. 57, pp. 87–94; January, 1940.

Antenna Impedance Measurement by Reflection Method*

EDWIN ISTVÁNFFY†

Summary—Two methods of measuring the impedance of radiators are described. They are based on measurement of the power reflected by the radiators. These methods are particularly useful for finding the radiation resistance of thick half-wave dipoles.

NUMEROUS PAPERS published during the last few years relating to antenna-impedance calculations and measurements are concerned with determining the radiation resistance of antennas in which the radius of the antenna conductor cannot be neglected. Although recently published new methods of calculation give better approximations, they are not adequate for a dipole in which $\Omega = 2 \log_n (2l/a) \leqq 10$, where $2l$ and a are the length and the radius of the dipole, respectively, and Ω is an often-used parameter determined by the length-to-thickness ratio of the conductor.

Impedance measurements commonly introduce discontinuities through coupling the dipole to the measuring equipment. These difficulties may be avoided by placing the antenna in the beam of a directional transmitter-receiver—like a radar target—and measuring the power reflected to the receiver.

The amplitude of the received signal depends on the *reflected power*, and the target distance for maximum reflected power depends on the *phase of the antenna impedance.*

By varying the length of a dipole, while retaining a constant thickness, the resonant length for a given wavelength may be found from the changes in reflected power.

Another check is to compare dipoles of different thicknesses, whose resonant lengths have been determined. If their resonant lengths correspond exactly, maximum reflection must occur at exactly the same target distances.

When the resonant lengths of dipoles having different length-to-thickness ratios are determined, a comparison of their reflective properties from the same target distance permits the ratio of their radiation resistances to be calculated.

If the field strength produced by the transmitter at the dipole is E_t the induced voltage in the dipole is $V = E_t h_{eff}$ where h_{eff} is the effective length of the dipole. The impedance of a dipole adjusted to its resonant length is equal to its radiation resistance (R_r). Thus, the reflected power is

$$P_r = \frac{E_t^2 h_{eff}^2}{R_r} \tag{1}$$

and the ratio of the reflected powers for two dipoles is

$$\frac{P_r''}{P_r'} = \left\{\frac{h_{eff}''}{h_{eff}'}\right\}^2 \frac{R_r'}{R_r''}. \tag{2}$$

The directional properties of resonant-length dipoles of different thicknesses show only small variations and, for small differences in length,

$$\frac{h_{eff}''}{h_{eff}'} = \frac{l''}{l'} \tag{3}$$

where l''/l' is the ratio of the resonant lengths of the two dipoles. The ratio of resistances, as derived from (2) and (3), is

$$\frac{R_r''}{R_r'} = \frac{P_r'}{P_r''}\left(\frac{l''}{l'}\right)^2. \tag{4}$$

Although this is a comparative method, the absolute value of the radiation resistances may also be found, provided the value of one of the tested dipoles is known.

Another method of determining radiation resistance is based on measured phase-angle data as a function of dipole length in electrical degrees. This method is not comparative. Using an impedance circle diagram, it is possible to determine the radiation resistance by plotting one part of the impedance locus curve.

1. Setup and Technique

The measurements were carried out on an athletic field. Horizontally polarized waves were used. Fig. 1 shows the equipment as set up for making measurements. On the table are the transmitting and receiving parabolic reflectors, which are of similar design. In

Fig. 1—The setup of equipment for making reflection measurements.

* Decimal classification: R221. Original manuscript received by the Institute, April 28, 1947; revised manuscript received, August 16, 1948.

† Standard Electric Co. Ltd., Budapest, Hungary.

front of the reflectors is a wooden track 2.5 meters (8.2 feet) long and 0.5 meter (1.6 feet) high, on which a little wooden carriage, which carries the dipole under test, can be moved by strings from behind the reflectors. The focal line of the reflectors was 1.5 meters (4.9 feet) above the ground and the axis of the dipole under test was set in each case to this height. An indicator fixed to the side of the carriage and a scale on the track, marked at every half centimeter, enabled the target distance to be determined within an accuracy of about 1 millimeter (0.04 inch).

A battery-operated 955 acorn triode produced an output power of about 0.1 watt at a wavelength of 55.2 cm (540 Mc). The transmitting dipole and its oscillator were placed in the focus of one of the parabolic reflectors, the apertures of which measured 69 by 50 cm (27 by 20 inches). For reducing the direct pickup by the receiver, the focus was 7 cm (2.75 inches) inside the aperture. The power gain of the reflector was 9.

The receiving dipoles and crystal rectifier were mounted in the other reflector, from which two wires were brought out through an rf filter to a meter. The detector was a silicon crystal with gold electrode and operated as a square-law rectifier.

Initially, a heavier carriage was used, but, even without a dipole, it caused significant changes in the meter deflection as it was moved. The structure of the carriage was gradually reduced to that shown in Fig. 1. With an initial deflection of 40 divisions on the receiving meter caused by direct pickup from the transmitter, a change of about 0.5 division or less resulted from moving the carriage along the track.

Tests made with dipole-supporting structures showed that, for thin antennas, the use of dielectric materials near the dipoles, especially at the ends, tended to decrease the resonant length and impair the response at resonance. To avoid these effects, the holder, shown in Fig. 2, was placed at the center of the dipole. The dipole is lying on two 1-mm (0.04-inch) phenol fiber plates 10 mm (0.39-inch) apart, and is held in position by a small rubber strip.

Some of the transmitted power picked up directly by the receiver and a relatively small amount reflected by the ground and distant objects produce an initial reading on the meter. Some efforts were made at first to compensate for these effects, but later it was obvious that this was unnecessary. The direct pickup causes a steady field at the receiver, to which the reflected field from the target dipole is added and when the target is moved, the phase of the reflected wave rotates, causing phase additions and oppositions with the steady field and alternate maximum and minimum deflections of the meter.

If the distance to the dipole target is large compared to that between the transmitting and receiving dipoles, the distance between adjacent maxima or minima is half the free-space wavelength. It may be shown that, with square-law detection, if the reflecting powers of two dipoles being tested are unequal, the difference in the meter deflections increases as the steady field becomes stronger. Further, there is an improvement in the accuracy of positioning the dipole for maximum deflection of the meter with increasing steady field, and the target-distance measurements make possible the calculation of the phase of the impedance.

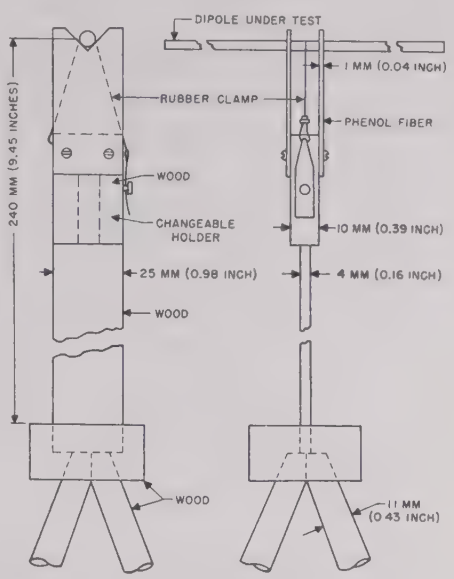

Fig. 2—The dipole support is changeable and is mounted at the top of the carriage.

If a dipole is made longer than its resonant length so that the current lags 45° behind the voltage, this will cause a time lag at the receiver that may be compensated for by moving the target 1/16 wavelength nearer to the transmitter-receiver. In this way, if the resonant length is known, the phase of the impedance can be determined.

2. Measurements

Five series of dipoles were tested; their diameters being 0.14, 0.48, 3, 13.6, and 40 mm (0.006, 0.019, 0.118, 0.535, and 1.575 inches). The first two sizes were of bare copper wire, and a series of different lengths ranging from 230 to 280 mm (9 to 11 inches) were prepared. The 3-mm dipoles were brass rods and a similar series were made. The dipoles of 13.6- and 40-mm diameters were brass tubes with 1-mm (0.04 inch) wall thickness and were adjustable in length. Both could be used with closed and open ends.

First, the field strengths were measured along the track of the target. For this purpose, a tuned dipole fitted with a thermocouple was placed on the holder and the readings on the linear scale of the meter were recorded for different distances. The plotted field power curve, which is proportional to the square of the field strength, is shown in Fig. 3. At a distance of 2.2 meters, there is a flat minimum caused by reflections from the

earth. From about 2 to 2.4 meters, the field power changes very little and, therefore, this range was considered to be most suitable for measurements.

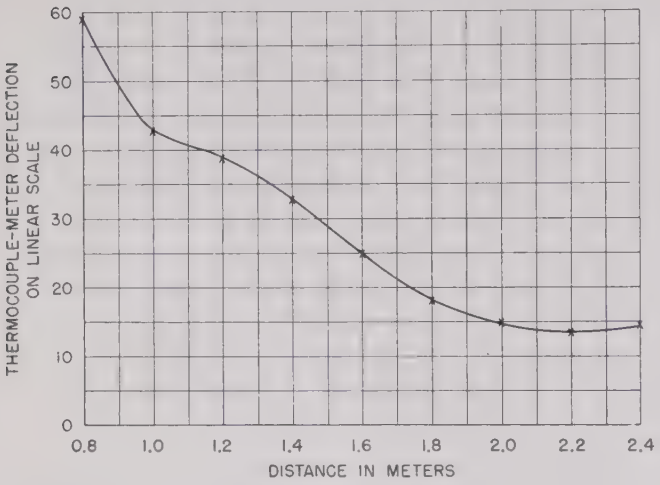

Fig. 3—The measured field-power curve along the track of the target. From about 2.0 to 2.4 meters, the field power is approximately constant and this range is most suitable for the measurements.

Fig. 4 shows the maxima and minima of the receiver meter deflections when moving a 3-mm dipole of resonant length along the track. A deflection of 41 divisions was obtained in the absence of a dipole. The square root values of the readings are proportional to the field strengths.

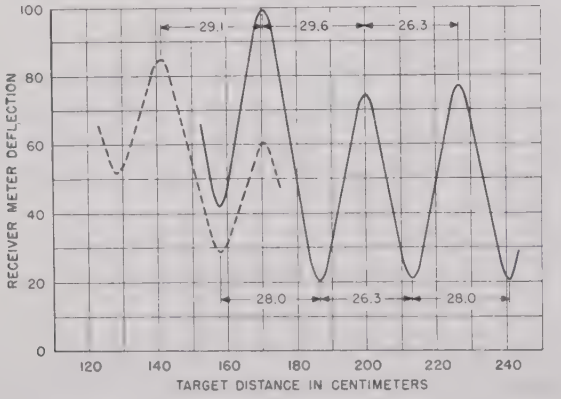

Fig. 4—Maximum and minimum deflections when moving a dipole along the track. The dotted curve is for 120 volts and the solid curve for 150 volts on the plate of the oscillating tube.

From Fig. 4, it is evident that the distances between adjacent maxima and minima show some irregularities. The average value, however, calculated from the sum of the last two maxima and minima, gives accurately the free-space half-wavelength used (276 mm).

Fig. 5 shows curves of the measured maximum deflections plotted against dipole lengths for different dipole thicknesses. The thinnest dipole gave the sharpest resonance curve, while the curve of the 40-mm dipole is so flat that the resonant length can hardly be determined from these measurements.

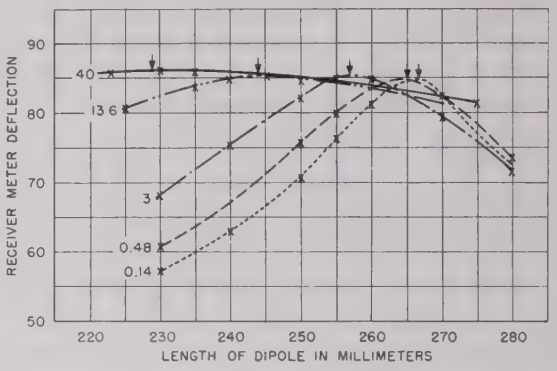

Fig. 5—Measured maximum deflections for dipoles of different lengths and diameters. The figures identifying the curves are the diameters of the dipoles in millimeters.

The target distances are plotted against dipole lengths in Fig. 6 for the five different diameters. On the co-ordinate scale, only target distances for the 0.14-mm dipoles are shown. For the other curves, only relative changes in distance are needed. The resonant lengths are marked with arrows. The inflection tangents are also drawn, giving a rough check of the correctness of the resonant

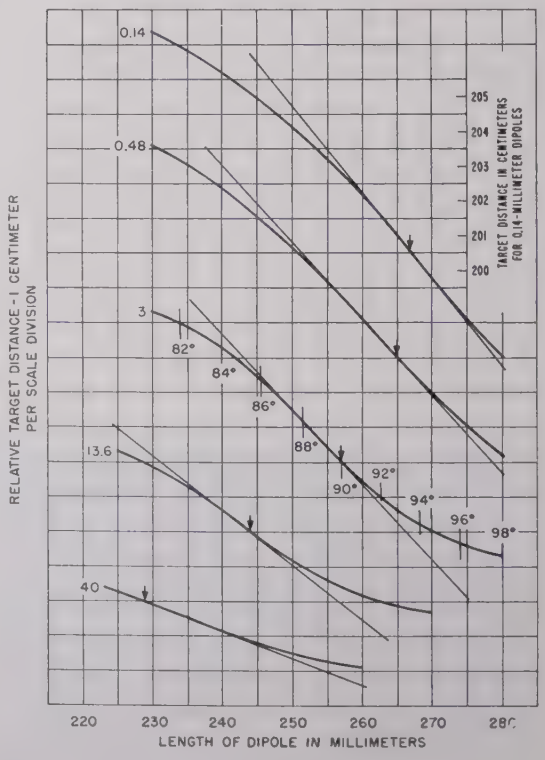

Fig. 6—The measured changes of target distances for dipoles of different lengths. The resonant lengths are marked with arrows. Actual distances are given for only one dipole thickness, 0.14 millimeter, the remaining curves being plotted against relative distances.

lengths. As may be seen, the angle of the tangents to the horizontal will be smaller with increasing dipole thickness.

3. Comparison of Reflected Power and Calculation of Radiation Resistance

To produce the highest useful deflection of the receiver meter, measurements were made at a target distance of 1.7 meters (67 inches) on the previously checked five resonant-length dipoles of different thicknesses.

The results are given in Table I. For the 0.48-, 3-, and 13.6-mm dipoles, the measured target distances are equal, which is a statistical proof of the correctness of the lengths. For the 40-mm dipole, the small difference in target distance was probably caused by the nonuniform current distribution around the surface of the dipole and for that reason no correction was made.

For the 0.14-mm dipole, the somewhat uncertain results of comparison were probably caused by the fact that a straight position of this very thin wire could not be secured. For this reason, it is not included in Table I.

For calculating the ratio of the reflected powers, the effect of the steady field must be eliminated. The corrected values were calculated by

$$\alpha_{cor} = (\sqrt{\alpha} - \sqrt{\alpha_0})^2, \qquad (5)$$

in which α_0 was 41 divisions, the value for the steady field. These corrected values are also given in Table I.

The loss resistance of the 0.48-mm dipole must not be neglected in these comparisons. Calculations showed that the reflected power decreases by about 2 per cent as a result of the loss resistance. Therefore, the ratios of radiation resistance calculated with (4) must be multiplied by 1.02. These ratios are included in Table I.

TABLE I

Diameter of dipole in millimeters	0.48	3	13.6*	40*
Diameter of dipole in inches	0.019	0.118	0.535	1.575
Resonant length in millimeters	265	257	244	229
Target distance in centimeters	171.4	171.4	171.4	171.6
Dipole length / Free-space half wavelength	0.96	0.931	0.885	0.83
Maximum receiver meter deflection	96.5	97.5	98	98.5
Corrected meter deflection, without steady field	11.7	12.0	12.25	12.4
Ratio of resistances	1	0.935	0.828	0.72
Radiation resistance based on 63 ohms for 3-millimeter dipole	67.5	63	55.8	48.5

* With closed ends.

To obtain numerical values of radiation resistance, use was made of one of the values of radiation resistances, determined by the phase method, dealt with in Section 4. The 3-mm dipole was chosen as its radiation resistance of 63 ohms was one of the most reliable values found, being only slightly influenced by the limitations of the measurement methods. The radiation resistances for the other dipoles were calculated from this value and the ratios, and are given in the last line of the table.

4. Calculation of Antenna Impedance from Phase Measurements

To calculate antenna impedance from phase measurements, an impedance circle diagram was prepared in chart units[1] as shown in Fig. 7. This represents an enlargement of only a small part of the usual diagram. The horizontal distances from the origin are equal to the resistive components, and the vertical distances to the reactive components of the impedances in chart units, i.e., the unit of the chart is the characteristic impedance of the line. The constant ϕ circles correspond to the lengths of the line in electrical degrees; $\phi = 90°$ represents the resonant length of a dipole.

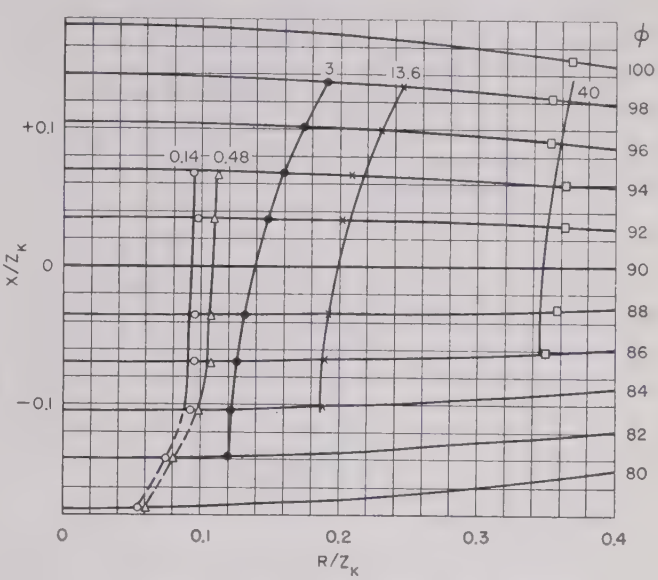

Fig. 7—Impedance locus curves plotted on an impedance circle diagram in chart units.

As an example, let us take the diagram of the 3-mm dipole. In Fig. 6, the resonant length was 257 mm, which is equal to 90 electrical degrees. Thus 1° corresponds to 2.8 mm change in length. Fig. 6 gives values from 82 to 98° for this dipole. The vertical distances, measured from the target distance of the resonant-length dipole, are proportional to the phase angles of the impedances. Half the free-space wavelength, i.e., 276 mm, corresponds to 360°, thus 1 mm on the vertical scale is equal to 1.3° of phase angle. For $\phi = 96°$, $\Delta D = -23$ mm, which corresponds to $23 \times 1.3 = +30°$ of phase angle. If we draw a line with a slope of 30° from the origin, then the intersection with the $\phi = 96°$ circle will give one point of the impedance spiral diagram.

A number of points are marked on Fig. 7 for dipoles of different thicknesses. The irregularities in some points indicate the presence of some disturbing effects, which seem to be greatest for the thinnest dipoles and when they are tuned off resonance.

[1] Massachusetts Institute of Technology, Radar School Staff, "Principles of Radar," McGraw-Hill Book Co., New York, N. Y., 1946; chap. 8, p. 58.

The radiation resistance at resonant length is obtained at the intersection of the impedance locus curve and the $X=0$ abscissa. It is customary to call this reading the "standing-wave ratio." Multiplying this value by the calculated characteristic impedance of the resonant-length dipole, we get the radiation resistance at the resonant length. The results are given in Table II, where the calculated values of the characteristic impedance and the parameter Ω are also tabulated. The radiation resistances of the first two dipoles could not be determined with certainty.

TABLE II

Diameter of dipole in millimeters	0.14	0.48	3	13.6	40
Diameter of dipole in inches	0.006	0.019	0.118	0.535	1.575
$\Omega=2\log_n(2l/a)$	16.2	13.8	10.2	7.15	4.87
Characteristic impedance of resonant length dipole in Ω, Z_k	830	678	456	269	130
Standing-wave ratio from Fig. 7	0.092	0.107	0.138	0.2	0.35
Radiation resistances at resonant lengths	76*	72.5*	63	53.9	45.5
Radiation resistances at resonant lengths without loss	73.5*	71.8*	63	53.9	45.5

* The position of these curves was somewhat uncertain.

Comparing these values with those of Table I, it may be seen that the agreement is fair enough, although two quite different methods have been used. The somewhat greater values for the thickest dipoles, as measured by the amplitude method, could probably be explained by the small change in directional characteristics of the dipoles of shorter length.

Some data for dipoles of varying-length-to-thickness ratio, calculated by different theories and also measured by the described methods, are given in Table III.

TABLE III[2,3]

$\Omega=2\log_n(2l/a)$	16.2	13.8	10.2	7.15	4.87
Hallen-Bowkamp, 1st order	63.1	61.54	58	—	—
Hallen-Bowkamp, 2nd order	68.7	66.5	60.4	—	—
Gray, modified, 1st, 2nd order	69.7	69.2	67.3	—	—
King-Middleton, 1st order	69.2	68.1	65	—	—
King-Middleton, 2nd order	70.85	70.82	70.77	—	—
Schelkunoff	66.7	65.2	61.4	—	—
Measurements					
Amplitude	—	67.5	63	55.8	48.5
Phase	—	—	63	53.9	45.5

[2] D. Middleton and R. King, "The thin cylindrical antenna: a comparison of theories," *Jour. Appl. Phys.*, vol. 17, pp. 273–284; April, 1946.

[3] S. A. Schelkunoff, "Electromagnetic Waves," fourth edition, D. Van Nostrand Company, New York, N. Y., October, 1945; p. 464.

For $\Omega=10.2$, best agreement with measured values is obtained with calculations based on the Schelkunoff and King-Middleton first-order formulas.

For the same dipole, some other measured and calculated values may be compared. For the free-space half-wave dipole, the measured impedance values according to Fig. 7 are: $R=82$ ohms, $X=53$ ohms, and phase angle $=32.5°$. According to Schelkunoff, these values are: $R=75$ ohms, $X=45$ ohms, and phase angle $=31°$. The King-Middleton second order gives: $R=88$ ohms, $X=42.5$ ohms, and phase angle $=25.8°$. The measured resonant length of this dipole was less by 0.095 radian than $\pi/2$, if $\pi/2$ corresponds to the free-space half-wavelength. According to the Schelkunoff and King-Middleton second-order calculations, this value was 0.094 radian.

For $\Omega<10$, unfortunately, no data were available for comparison.

Measurements made with open-ended tubes for the 13.6- and the 40-mm dipoles showed no practical differences in resonant lengths and in reflected powers.

4.1 Limitations

The slight effect of the carriage and probable small changes in earth reflections when moving the target may cause some irregularities in the steady field and in the meter deflections, especially for thin and detuned dipoles. This was substantiated by irregularities observed between adjacent maxima and minima when moving the target. Deviations in the impedance locus curves may result. Further, difficulties in obtaining accurately straight positions of thin wires made the equipment most suitable for determining the impedances of relatively thick dipoles. For the thickest dipoles, changes in target distance versus dipole length were small, and the accuracy of setting limited the results. With the amplitude method of comparing reflected powers, the effect of these factors was reduced.

During measurements, the anode voltage was maintained at 160 ± 0.2 volts, and the crystal detector proved to be very stable. The accuracy of the wavelength measurements was about ±1 mm.

CORRECTION

The following errors have been brought to the attention of the editors by a communication from Leon Riebman, author of the paper, "Theory of the superregenerative amplifier," which appeared on pages 29–34 of the January, 1949, issue of the PROCEEDINGS OF THE I.R.E.

In equations (2) and (4) the limits on the integral $\epsilon^{1/2\int_t^\tau P dt}$ should be τ, not r.

On page 30, under definitions of symbols,

t_Y (not t_τ) = duration of decay phase

$t_Y+t_S=t_D$ (not t_0)

$G^R(t)=G(t_i,\ t_i+t_D)$, not $G(t_1t_i+t_D)$.

Measured Impedance of Vertical Antennas Over Finite Ground Planes*

A. S. MEIER† AND W. P. SUMMERS‡, ASSOCIATE, IRE

Summary—An investigation was made to obtain some fundamental information concerning the relation of the impedance of a vertical antenna over a finite ground plane as a function of the size and shape of the ground plane when dimensions of the ground plane are relatively small in terms of wavelength. It was found that the input impedance is a damped oscillating function of wavelength and ground-plane dimensions, the impedance of a circular ground plane varying from ±5 to ±20 per cent. Similar variations were observed on a square ground plane, which were approximately 50 per cent of those of the circular ground plane except when the dimensions of the ground plane were small. In general, it was found that the impedance is quite critical with respect to the size and shape of the ground plane, and relatively independent of the thickness of the antenna.

Measurements were made at microwaves by a modified Chipman method capable of measuring small differences in antenna impedance. Recent emphasis on improved microwave measurement techniques led to the investigation of the merits of the Chipman method as compared to those of the more conventional slotted-line standing-wave method. Although the two methods are shown to be closely related from a theoretical viewpoint, practical mechanical and electrical limitations are encountered which dictate preference of method entirely dependent on the application.

I. Introduction

IN MEASURING experimentally the impedance of unbalanced antennas, it is the general practice, in many cases, to select arbitrarily a ground plane of convenient dimensions, the size and shape being dictated solely by practical considerations. A great many impedance problems involve unbalanced antenna systems for which practical ground planes cannot be constructed conveniently in excess of five or six wavelengths, and there is little information in the literature to guide the investigator in determining the relation between the antenna input impedance and ground-plane configuration. The investigation covered in Section II of this paper was undertaken with a view toward providing some much needed basic information on simple ground-plane structures to determine the antenna impedance as a function of the size and shape of the ground plane when the dimensions of the ground plane are relatively small in terms of wavelength.

The method of measurement is discussed in Section III. The equipment and techniques of measurement were developed for scale-model antenna measurements at microwaves, with particular emphasis on a high order of accuracy and a wide range of impedance.

* Decimal classification: R221×R244.21. Original manuscript received by the Institute, June 1, 1948; revised manuscript received, September 29, 1948. Presented, 1948 IRE National Convention, New York, N. Y., March 22, 1948. The basic development of microwave measuring equipment and techniques was undertaken at the direction of the Army Air Forces, Wright Field, Dayton, Ohio, under War Department Contract 33-038ac13493.

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II. Antenna Impedance over Finite Ground Planes

Antenna impedance measurements were made on circular and square ground planes varying in dimensions from 1.7 to 6.1 wavelengths. Two antennas, a "thick" antenna 0.0258λ in diameter and a "thin" antenna 0.0060λ in diameter, were measured at a fixed frequency and were varied in length from 0.163λ to 0.529λ. The actual wavelength used was 12.28 cm. Details of the antenna and ground-plane mountings are shown in Fig. 1.

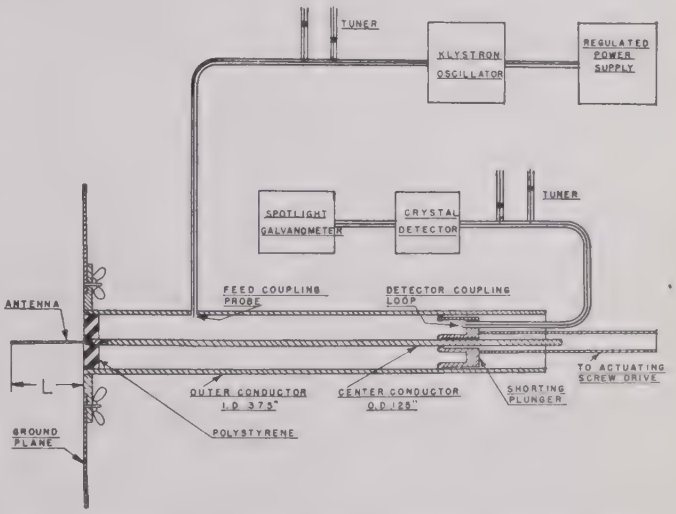

Fig. 1—Antenna and ground-plane mounting, Chipman coaxial measuring line and associated components.

A polystyrene bead was used to support the antenna, as shown in Fig. 1. In calculating the antenna impedance at the base of the antenna, the measured impedance was transformed through the polystyrene section which was treated as a uniform length of transmission line having a characteristic impedance of 41.5 ohms and an electrical length of 22.13°. The characteristic impedance of the measuring line was 66.0 ohms. Any error introduced by the polystyrene section does not necessarily invalidate results, since the basic ground-plane investigation involves only variations of impedance.

Measurements were made with the antenna and ground plane projecting through a second-floor window, with the ground plane located approximately two wavelengths beyond the outside wall of a brick building.

Circular Ground Planes

Initial measurements were made with the 0.0060λ-diameter antenna on three circular ground planes of

widely varying size in order to determine the approximate magnitude of impedance variation. The measured impedances are shown in Fig. 2. In Fig. 2 it will be

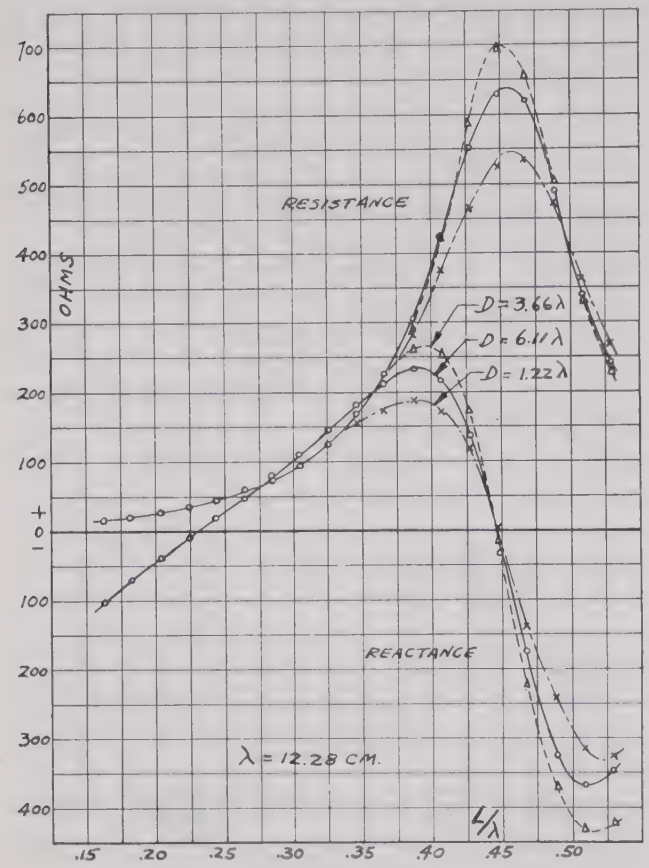

Fig. 2—Antenna impedance as a function of antenna length L for three circular ground planes of varying diameter D.

noted that the impedance of the antenna of the 6.11λ-diameter ground plane falls within the values of the impedance of the 1.22λ- and 3.66λ-diameter ground planes which suggests, as would be expected, that the variation in impedance is an oscillating function of wavelength and ground-plane diameter. The magnitude of the impedance variation for the three arbitrarily chosen ground planes is somewhat larger than was first anticipated. It was observed that a considerable variation exists; the resonant resistance varies between 33 and 43 ohms, the antiresonant resistance varies between 545 and 700 ohms, and the maximum reactance values vary between +185 to +265 ohms and −335 to −435 ohms.

Figs. 3 and 4 show the results of measurements of the two antennas over ground planes varying from 1.7λ to 3.5λ in diameter. The results indicate comparable amplitudes of oscillation for both "thick" and "thin" antennas and a noticeable damping of oscillation as the ground plane increases in size. Rather large magnitudes of variation are evident which indicate that the antenna impedance is very critical with respect to the ground-plane dimensions.

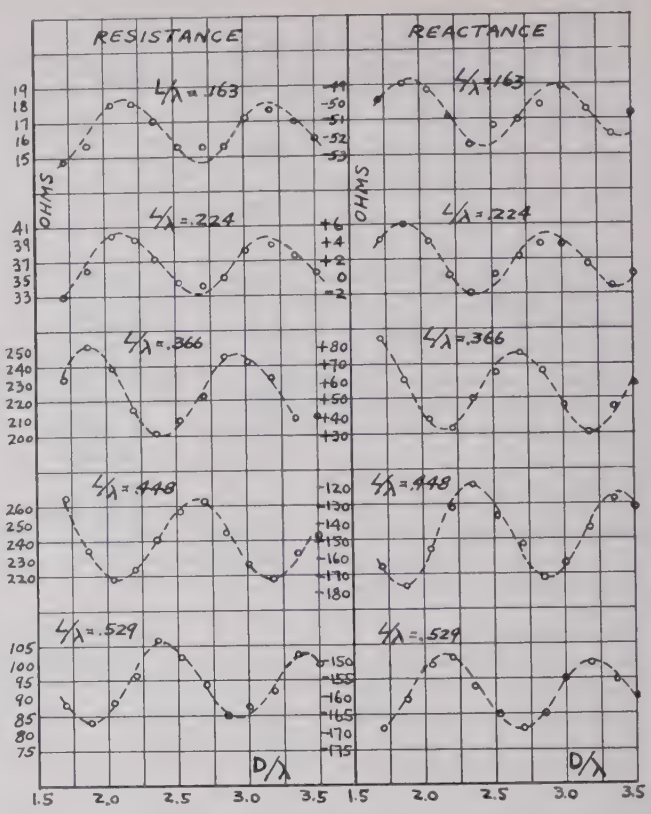

Fig. 3—Circular ground plane—Impedance of 0.0258λ-diameter antennas for ground-plane diameters D varying from 1.7 to 3.5λ.

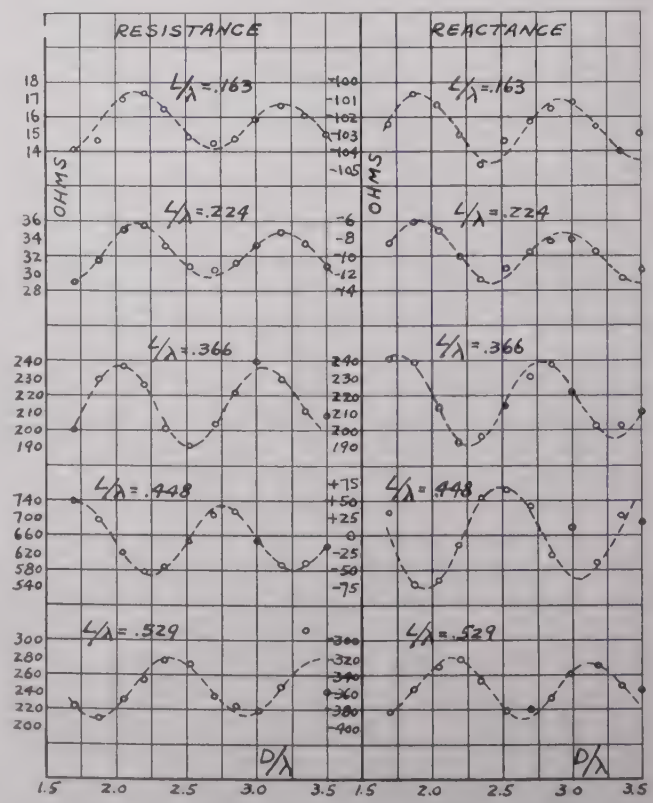

Fig. 4—Circular ground plane—Impedance of 0.0060λ-diameter antennas for ground-plane diameters D varying from 1.7 to 3.5λ.

Measurements were next extended to a ground-plane diameter of six wavelengths in increments of 2 cm for both "thick" and "thin" antennas. Two antenna lengths were chosen which approximated resonant and antiresonant antenna lengths. The results of these measurements are shown in Figs. 5 and 6. The variations in resistance amount to approximately ± 5 to ± 15 per cent and comparable variations in reactance exist except when the reactance approaches zero and the percentage variation thus becomes meaningless.

Square Ground Planes

Measurements of impedance were made on square ground planes, the same two antenna lengths of both "thick" and "thin" antennas being used so that a direct comparison could be made with the circular ground planes shown in Figs. 5 and 6. The results of the square

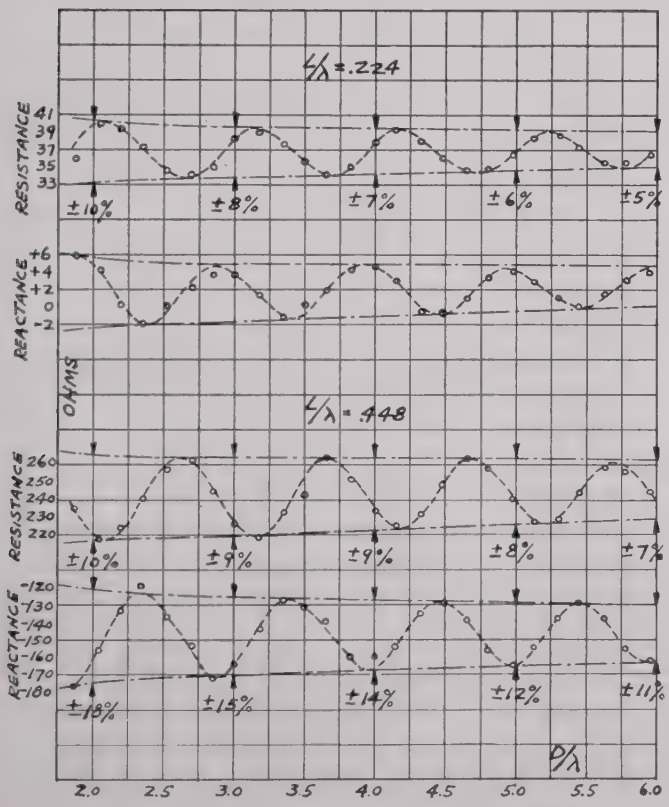

Fig. 5—Circular ground plane—Impedance of 0.0258λ-diameter antennas extended to 6λ-diameter ground plane.

ground-plane measurements are shown in Figs. 7 and 8. The results indicate comparable amplitudes of oscillation for both "thick" and "thin" antennas and a gradual damping of oscillation as the ground-plane increases in size. The larger variations in impedance occur for the smaller ground-plane sizes, increasing rapidly when the lateral dimensions of the ground planes are less than 2.5λ.

The amplitudes of oscillation of the square ground planes are considerably less than those of the circular

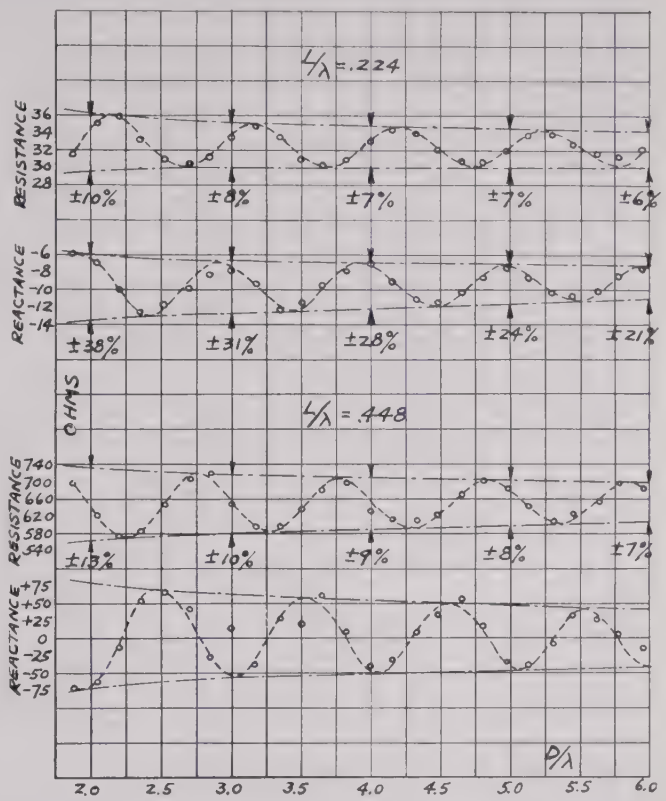

Fig. 6—Circular ground plane—Impedance of 0.0060λ-diameter antennas extended to 6λ-diameter ground plane.

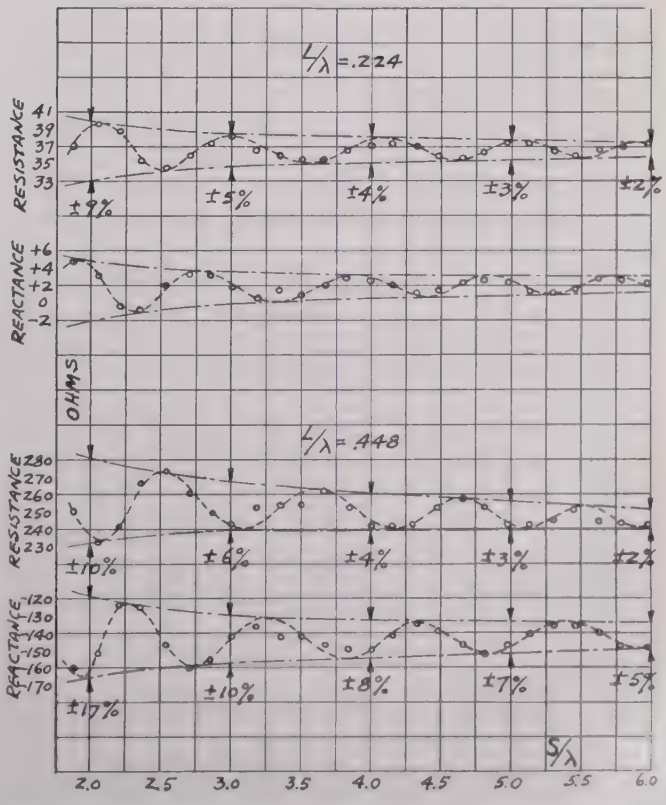

Fig. 7—Square ground plane—Impedance of 0.0258λ-diameter antennas as a function of ground-plane side dimension *S*.

ground planes, and the damping of oscillation is more rapid. In general, the variations in impedance are approximately 50 per cent of the variations of the circular ground planes except when the dimensions of the ground planes are small.

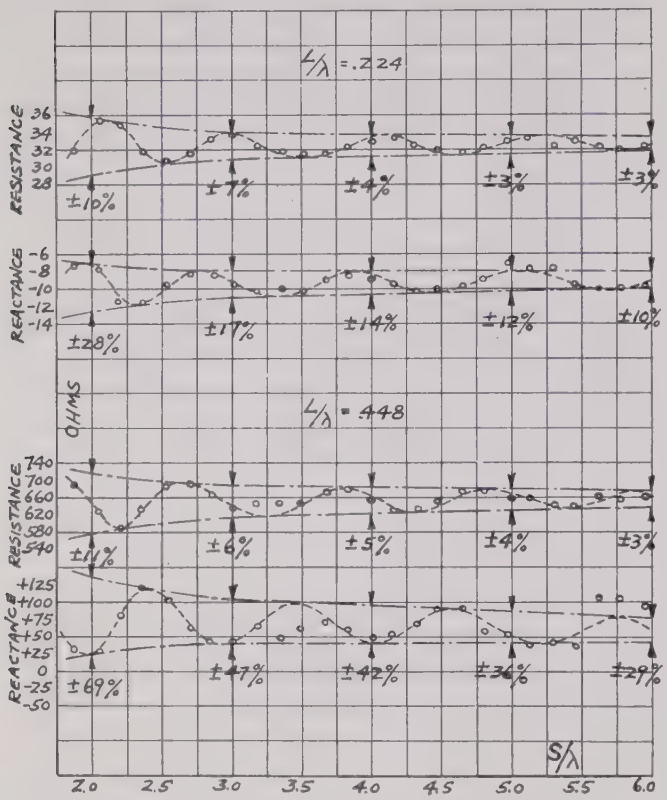

Fig. 8—Square ground plane—Impedance of 0.0060λ-diameter antennas as a function of ground-plane side dimension S.

Difficulty was experienced with the measuring equipment when the square ground-plane measurements were taken. Deterioration of contact occurred due to excessive wear of the fingers of the movable shorting plunger. Measurements were further complicated at this point by the oscillator tube giving out, causing fluctuations in the output voltage. Measurements of the square ground planes were repeated using a new oscillator tube which was adjusted as close to the original frequency as the cavity adjustment permitted, and temporary repairs were made to the contact fingers in order to complete the investigation. After repeating data, it was found that the contact difficulty had not been entirely corrected, so that the curves of Figs. 7 and 8 were finally plotted from composite data of the two sets of measurements. This accounts for some of the irregularities in the data.

III. Method of Measurement

A modified Chipman[1] method was used to measure the impedance of the antennas discussed in Section II. The Chipman methods has not been used extensively at microwaves, so that a discussion of the application is given in the following analysis, which differs from the original Chipman paper in that the derivation is made to afford a direct comparison with the more conventional standing-wave slotted-line method.

Fig. 1 shows the arrangement of the measuring system. The measuring line consists of a coaxial line fitted with an adjustable shorting plunger containing a very small detecting loop. The line is excited near the load end of the line by means of a voltage probe coupled to the generator. The actuating screw which drives the plunger is connected to a vernier system graduated to 1/10,000 cm. As in the standing-wave slotted-line method, two quantities determine the unknown load impedance: (1) the magnitude of the "standing-wave ratio" of current through the shorting plunger as the electrical length of the measuring line is changed by movement of the plunger, and (2) the position of this simulated "standing-wave" on the transmission line.

Chipman Method

Consideration is given to the ideal case, in which it is assumed that the measuring line is lossless and the generator impedance is zero.

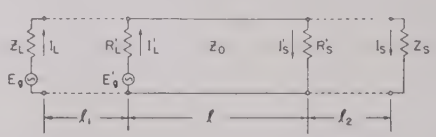

Fig. 9—Generalized transmission line for computing the equivalent standing wave due to the load and plunger impedance, Chipman method.

Referring to Fig. 9, the complex load impedance Z_L is transformed to a real impedance R_L' through an appropriate length of transmission line l_1, and, similarly, the shorting plunger and receiver impedance Z_s is transformed to a real impedance R_s' through a corresponding length of line l_2.

Considering the voltage relation in terms of real impedances,

$$E_g' = I_L'R_L' + I_s'[R_s' \cos \beta l + jZ_0 \sin \beta l] \quad (1)$$

$$E_g' = \frac{I_s'}{Z_0}[Z_0(R_L' + R_s') \cos \beta l + j(Z_0^2 + R_L'R_s') \sin \beta l]. \quad (2)$$

Let

$$\frac{R_L'}{Z_0} = \frac{1}{\rho_L} \quad \text{and} \quad \frac{R_s'}{Z_0} = \frac{1}{\rho_s},$$

ρ_L representing the mismatch between the load impedance and the transmission line alone and ρ_s that due to the mismatch of the plunger impedance and line.

[1] R. A. Chipman, "A resonance curve method for the absolute measurement of impedance at frequencies of the order of 300 Mc," *Jour. Appl. Phys.*, vol. 10, pp. 27–38; January, 1939.

Then

$$|I_s'|^2 = \frac{|E_g'|^2}{Z_0^2\left[\left(\frac{1}{\rho_L}+\frac{1}{\rho_s}\right)^2+\left(1-\frac{1}{\rho_L^2}\right)\left(1-\frac{1}{\rho_s^2}\right)\sin^2\beta l\right]}. \tag{3}$$

From (3), when $\rho_L>1$ and $\rho_s>1$, $|I_s'|^2$ is maximum when $\sin^2\beta l=0$ (i.e., when $l=n\lambda/2$), and $|I_s'|^2$ is minimum when $\sin^2\beta l=1$ (i.e., when $l=(2n-1)\lambda/4$).

$$\frac{|I_s'|_{\max}}{|I_s'|_{\min}} = \rho_0 = \frac{\rho_L\rho_s+1}{\rho_L+\rho_s} \tag{4}$$

where ρ_0 is the apparent "standing-wave ratio" of current measured directly on the line. From (4),

$$\rho_L = \frac{\rho_0\rho_s-1}{\rho_s-\rho_0} = \frac{Z_0}{R_L'}. \tag{5}$$

The terms ρ_L and ρ_s represent standing-wave ratios associated with the load- and plunger-impedance mismatches to the transmission line, respectively.

It will be noted that (4), expressed in terms of reflection coefficients, reduces to

$$|K_0| = |K_L|\cdot|K_s|$$

where

$$|K| = \frac{\rho-1}{\rho+1}. \tag{6}$$

Equation (4), in terms of reflection coefficients, corresponds to Chipman's original derivation:

$$\frac{|I_s'|_{\max}}{|I_s'|_{\min}} = \rho_0 = \frac{1+|K_L|\cdot|K_s|}{1-|K_L|\cdot|K_s|}. \tag{7}$$

Determination of high standing-wave ratios by direct measurement of current maxima and minima as in (4) and (7) is usually limited by the range of the galvanometer, especially when a square-law detector is used. High standing-wave ratios, however, may be measured more accurately by determining the current distribution near a maximum-current position.

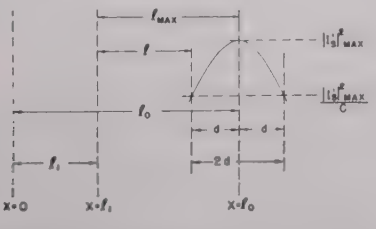

Fig. 10—Configuration for determination of the equivalent standing-wave ratio by determining the current distribution near a current maximum position, Chipman method.

Referring to Fig. 10, $|I_s'|_{\max}^2$ will be reduced to $|I_s'|_{\max}^2/C$ by moving the shorting plunger a distance d from the current maximum position. Then, from (3),

$$\frac{|I_s'|_{\max}^2}{|I_s'|^2} = C = \frac{\left(\frac{1}{\rho_L}+\frac{1}{\rho_s}\right)^2+\left(1-\frac{1}{\rho_L^2}\right)\left(1-\frac{1}{\rho_s^2}\right)\sin^2\beta l}{\left(\frac{1}{\rho_L}+\frac{1}{\rho_s}\right)^2}. \tag{8}$$

Then,

$$(C-1)(\rho_L+\rho_s)^2 = (\rho_L^2-1)(\rho_s^2-1)\sin^2\beta l. \tag{9}$$

Solving for ρ_L in (9),

$$\rho_L = \frac{\rho_0\rho_s-1}{\rho_s-\rho_0}$$

where

$$\rho_0 = \sqrt{\frac{C-1}{\sin^2\beta l}+1}. \tag{10}$$

Since

$$l = l_{\max} - d = n\lambda/2 - d,$$

$$\rho_0 = \sqrt{\frac{2(C-1)}{1-\cos 2\beta d}+1}. \tag{11}$$

Using the transmission-line equation to find the unknown load impedance Z_L,

$$\frac{1}{\rho_L} = \frac{R_L'}{Z_0} = \frac{Z_L+jZ_0\tan\beta l_1}{Z_0+jZ_L\tan\beta l_1}. \tag{12}$$

From Fig. 10.

$$\tan\beta l_1 = \tan\beta(l_0-l_{\max}) = \tan\beta l_0. \tag{13}$$

Solving for Z_L from (12) and (13),

$$Z_L = R_L + jX_L = \frac{\rho_L Z_0(1+\tan^2\beta l_0)}{\rho_L^2+\tan^2\beta l_0} + j\frac{(1-\rho_L^2)Z_0\tan\beta l_0}{\rho_L^2+\tan^2\beta l_0}. \tag{14}$$

The quantity ρ_s maybe determined from short-circuit measurements by use of (4), and once ρ_s and ρ_0 are known, (14) may be directly applied to determine the unknown load impedance Z_L.

Standing-Wave Method

The standing-wave slotted-line method of impedance measurement consists of a fixed length of transmission line terminated in a load impedance Z_L, the generator

being tightly coupled to the line. A traveling detector measures the voltage or current distribution along the line from which the unknown impedance Z_L is calculated.[2-4]

The complex load impedance Z_L of Fig. 11 is transformed to a real impedance R_L' through an appropriate length of transmission line l_1. Considering, then, the voltage relationship in terms of real impedances,

$$E = I_L'[R_L' \cos \beta l + jZ_0 \sin \beta l]. \tag{15}$$

Then,

$$|E|^2 = |I_L'|^2[R_L{}^{2\prime} \cos^2 \beta l + Z_0{}^2 \sin^2 \beta l]. \tag{16}$$

Let

$$\frac{R_L'}{Z_0} = \frac{1}{\rho_L}.$$

Then

$$|E|^2 = |I_L'|^2 Z_0{}^2 \left[\frac{1}{\rho_L{}^2} + \left(1 - \frac{1}{\rho_L{}^2}\right) \sin^2 \beta l\right]. \tag{17}$$

Thus, when $\rho_L > 1$, $|E|^2$ is maximum when $\sin^2 \beta l = 1$, (i.e., when $l = l_{\min} \pm \lambda/4 = (2n-1)\lambda/4$), and $|E|^2$ is minimum when $\sin^2 \beta l = 0$ (i.e., when $l = l_{\min} = n\lambda/2$).

Then

$$\frac{|E|_{\max}}{|E|_{\min}} = \rho_L = \frac{Z_0}{R_L'}. \tag{18}$$

As before, high standing-wave ratios may be readily measured by determining the voltage distribution near a voltage minimum instead of direct measurement of voltage maxima and minima as in (18). Referring to Fig. 11, $|E|_{\min}{}^2$ will be increased to $C|E|_{\min}{}^2$ by moving the traveling detector a distance d from a voltage minimum position. Then

$$\frac{|E|^2}{|E|_{\min}{}^2} = C = (\rho_L{}^2 - 1) \sin^2 \beta l + 1. \tag{19}$$

Since $l = l_{\min} - d = n\lambda/2 - d$, (19) reduces to

$$\rho_L = \sqrt{\frac{2(C-1)}{1 - \cos 2\beta d} + 1}. \tag{20}$$

Equations (12) through (14) are directly applicable for calculating the unknown impedance Z_L, once ρ_L and l_0 are known.

It will be noted that the Chipman and standing-wave methods are theoretically similar except for the introduction of the plunger impedance in the circuit. For low standing-wave ratios (when $\rho_s \gg \rho_L$) the plunger impedance has negligible effect as shown in Fig. 12 and the determination of impedance of the unknown, when assuming $\rho_s = \infty$, is exactly that of the standing-wave method.

Effect of Attenuation

In the previous analysis, it is assumed that the measuring line is lossless. In a very few instances, it may be correctly assumed that the errors due to attenuation are negligible and in most cases, especially at microwaves and even at very low frequencies where high standing-wave ratios are encountered, attenuation corrections are of prime importance for accurate measurements. Simple corrections for attenuation may be made by correcting the directly measured values by the following relations:

	Lossless Case	*Attenuated Case*
1. Measured *SWR*	$\rho_0 = \sqrt{\frac{2(C-1)}{1 - \cos 2\beta d} + 1}$	$\rho_\alpha \cong \sqrt{\frac{2(C-1)}{1 - \cos 2\beta d} + 1}$
2. *SWR* corrected for Attenuation	. . . . .	$\rho_0 \cong \frac{\rho_\alpha - \alpha l_0}{1 - \rho_\alpha \alpha l_0}$

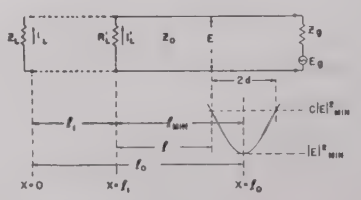

Fig. 11—Generalized transmission line for computing the standing-wave ratio by measurements about a voltage minimum, standing-wave method.

The relative magnitudes of the attenuation correction are shown in Fig. 12. The above formulas may be rigorously developed by assuming $\tanh \alpha l \cong \alpha l$ and $\alpha d \cong 0$, which are well within the experimental error of a well-designed measuring system. The term α is defined by the usual relation $\gamma = \alpha + j\beta$ where γ is the propagation constant and α and β the attenuation and phase constants of the measuring line.

In the Chipman method, the measured plunger-impedance mismatch must be corrected for attenuation. Although α may be determined within an experimental error of 5 per cent, applying this correction to the

[2] R. W. P. King, H. R. Mimno, and A. H. Wing, "Transmission Lines, Antennas and Wave Guides," McGraw-Hill Book Co., New York, N. Y., 1945; pp. 36–41.

[3] F. J. Gaffney, "Microwave measurements and test equipments," Proc. I.R.E., vol. 34, pp. 775–780; October, 1946.

[4] R. F. Lewis, "Measurements in the uhf spectrum," *Electronics*, vol. 15, pp. 63–68; April, 1942.

plunger-impedance mismatch ρ_s results in a much larger error in ρ_s. For the measuring line used in Section II, the value of ρ_s corrected for attenuation was found to be of the order of 600 to 1 within an error of approximately 20 per cent. However, when $\rho_s \gg \rho_L$ as in the case of the antennas measured in Section II, very accurate measurements are obtained in spite of the apparently large error in ρ_s.

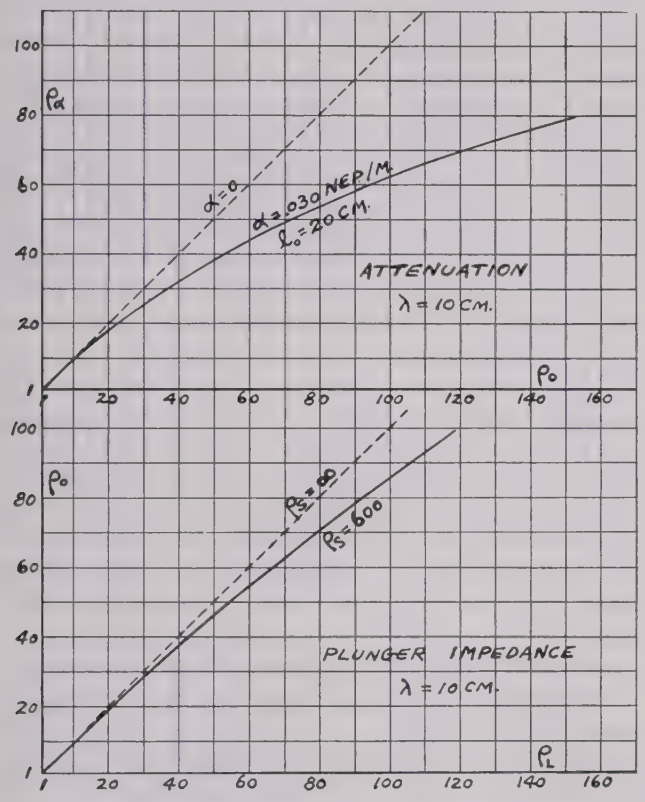

Fig. 12—Effects of attenuation and plunger impedance, Chipman method.

Careful consideration of the attenuation effect is essential in the calibration of the detecting system. Usually, a direct calibration is made on short circuit which is accurate only within certain limitations. In the Chipman method, a direct calibration may be made providing $\sin \beta l \gg 1/\rho_s + \alpha l$. In the measuring line used in Section II, a direct calibration can be made only in the range $14° < \beta l < 166°$ in order to satisfy this relation without exceeding an error of 1/10 per cent in power. Thus, it is essential to make a direct calibration more than 14° away from a current maximum position. The same condition applies to the standing-wave method for the condition $\sin \beta l \gg \alpha l$.

Effect of Coupling Impedances

In the theory it was assumed that the generator impedance in the Chipman method is zero. This is not rigorous since, obviously, it is necessary to introduce a discontinuity in the electromagnetic field in order to excite the measuring system. Attempts have been made to analyze the effect of the probe[5] in connection with discrepancies observed in slotted-line measurements by the standing-wave method. Rather than attempt corrections of the effect of the probe, satisfactory results have been obtained by minimizing the effect of the voltage probe by extremely loose coupling, so that only negligible error exists in neglecting the probe impedance. In practical measurements, this error can be made small enough so that it does not exceed other inherent errors of the system. Two precautions are necessary: (1) considerable power must be used, so that only very small penetrations of the probe are required, and (2) the probe must be inserted in a region of low electric field. These are rather stringent requirements, since small penetrations in a region of low electric field result in very inefficient coupling, requiring considerable generator power and a very sensitive detecting system.

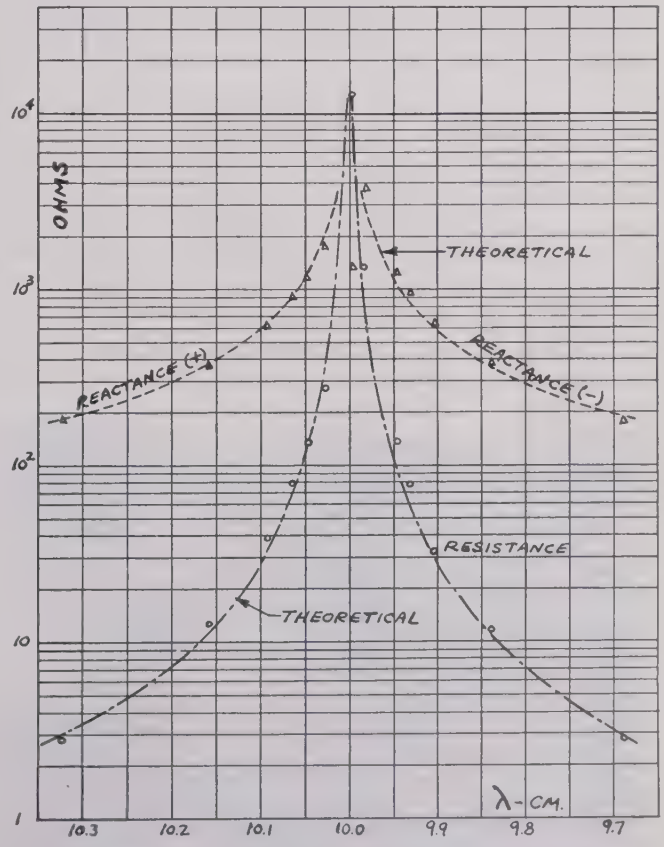

Fig. 13—Measured and theoretical impedance of a $1\frac{3}{4}$-wavelength short-circuited transmission line, Chipman method.

In the Chipman method, the effect of coupling to the detecting system must be given equal consideration. Favorable results may be obtained by using an extremely small coupling loop at the shorting plunger.

[5] William Altar, P. B. Marshall, and L. P. Hunter, "Probe error in standing-wave detectors," Proc. I.R.E., vol. 34, pp. 33P–44P; January, 1946.

This loop must be small enough so that the impedance introduced by the plunger and detector will approximate a very nearly ideal short circuit in order to achieve a maximum range of measurable load impedance with minimum effect of tuning of the detecting system.

A check of the accuracy of the measuring system used in Section II was made by measuring the apparent input impedance of a $1\frac{3}{4}$-wavelength short-circuited transmission line. The input impedance is of such magnitude that standing-wave ratios of 180 to 1 are involved. The probe was located at a distance two wavelengths from the short circuit, at a *voltage minimum* point, and adequate excitation was obtained with a small penetration when using a klystron oscillator with an output power of the order of two watts. The results of these measurements shown in Fig. 13 indicate the validity of neglecting the probe impedance for standing-wave ratios of practical significance. These measurements also show that the measuring system is capable of a relatively high order of accuracy in terms of absolute measurement of impedance.

General Limitations

The previous analysis indicated that the Chipman and standing-wave methods of impedance measurement are comparable from a theoretical standpoint. Physical realization of the measuring systems bring about practical electrical and mechanical limitations which dictate preference of method entirely dependent upon the particular application.

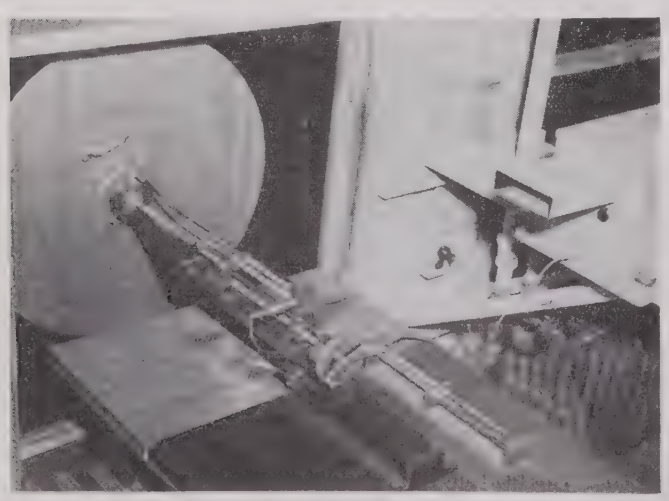

Fig. 14—Photograph of Chipman measuring line and associated components.

In the standing-wave method, very close machining tolerances must be maintained in the cross-sectional dimensions in both conductor and probe spacings. If variations exist in the spacing of the traveling probe with respect to either conductor of the measuring line, random variations in measured voltage will occur which cannot be compensated for by any simple procedure. This necessitates extremely accurate machining, which is difficult and expensive. (Fig. 14.)

Although the Chipman measuring line requires considerably less machining precision than that required in the standing-wave method, it is felt that the major difficulty encountered with the Chipman line is caused by the sliding contact of the movable shorting plunger. Considerable difficulty was experienced in maintaining uniform contact over a period of time, since the contact fingers of the movable shorting plunger deteriorated with wear, requiring replacement of the plunger and subsequent need for recalibrating the measuring system. On the other hand, it is felt that the Chipman method has a distinct advantage at microwave frequencies, since a longitudinal slot is not necessary in the outer conductor.

Although very loose coupling of the detecting system is required in the standing-wave method, the generator may be tightly coupled to the measuring line which permits use of easily available low-power oscillators in conjunction with a sensitive detecting system. In the Chipman method, loose coupling of both generator and detector requires considerably greater generator power, which is not generally available over wide ranges of frequency, especially in the microwave region.

As previously pointed out, accurate measurements by the Chipman method may be made when $\rho_s \gg \rho_L$, ρ_s and ρ_L being the standing-wave ratios associated with the plunger- and load-impedance mismatches, respectively. With the present measuring line operating at a wavelength of 10 cm, $\rho_s \cong 600$, which indicates that very good accuracy can be obtained when $\rho_L < 50$, i.e., when ρ_L is relatively small compared to ρ_s. Fairly good measurements may be made to values of $\rho_L = 200$, as shown by the results of Fig. 13, but poor results on an absolute basis are obtained for higher values when ρ_L and ρ_s are comparable in magnitude. This indicates that the Chipman method is not particularly adaptable to the measurement of extremely high standing-wave ratios.

ACKNOWLEDGMENT

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Some Properties of Radiation from Rectangular Waveguides*

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Summary—**Certain exact relationships between the radiation pattern and impedance characteristics of a radiating rectangular waveguide with vanishingly thin walls are developed. In particular, it is shown that the ratio of radiation intensities in certain preferred directions and the power gain in these directions are related in a simple manner to the reflection coefficient inside the waveguide. Although the information obtained is restricted in the sense that it applies to only a few discrete points on the radiation pattern, it is quite general as regards the manner in which the waveguide is broken or perforated to allow radiation. The results are shown to apply equally well if conducting sheets, having arbitrary shapes but lying on specified planes, are present in the vicinity of the radiating waveguide.**

I. Introduction

IT IS POSSIBLE to write various free-space solutions to Maxwell's equations in which there appear "null planes" or planes having no tangential component of electric field. It is readily shown that thin conducting sheets may be inserted into the null planes of such a field without affecting the validity of the solution. The conducting sheets may, of course, coincide with all or any parts of the null planes. It follows that many well-known solutions to simple radiation problems are, at the same time, solutions to a variety of diffraction problems involving conducting sheets whose dimensions are completely arbitrary.

The problems which may be solved by simply inserting conducting sheets into the null planes of a known field are usually of little importance in themselves. In some cases, such as those discussed below, however, solutions obtained in this fashion may be used in conjunction with the principles of superposition and reciprocity to obtain more information than can be extracted from these general principles alone.

II. Construction of the Fields for the Waveguide Problem

Consider two dipole sources a and b (Fig. 1) which are polarized in the z direction and which have their centers in the plane $z=0$ at points symmetrical about the y axis. If the distance r is large compared with the wavelength, the fields in the vicinity of the origin due to a and b may be approximated by plane waves with directions of propagation making angles of $\pi+\theta_0$ and $\pi-\theta_0$ with the y axis, respectively. If the two sources are fed with signals of equal amplitude and phase, the resultant electric field in the vicinity of the origin calculated on the basis of the plane-wave approximation is readily shown to be

$$E_z = 2E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0} \qquad (1)$$

where the time factor $e^{j\omega t}$ has been omitted, $k=2\pi/\lambda$, and E_0 is the rms amplitude of the field at the origin due to either source (rationalized mks units are employed throughout the discussion). We will be concerned with the case $r=\infty$, so that the plane-wave approximation becomes exact, and (1) is valid for all finite values of x, y, and z.

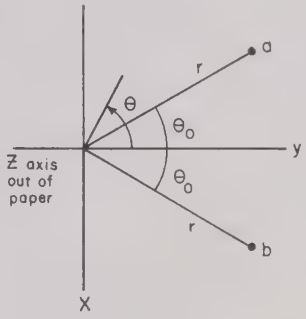

Fig. 1

It is seen that the electric field vanishes along planes which are parallel to the plane $x=0$ and which occur at values of $x=\pm n\lambda/4 \sin\theta_0$, where n may have odd integral values. In addition, it is noted that any plane parallel to the plane $z=0$ has no tangential component of electric field. Thin conducting sheets may now be located so that they coincide with parts of these null planes without changing the solution given by (1).

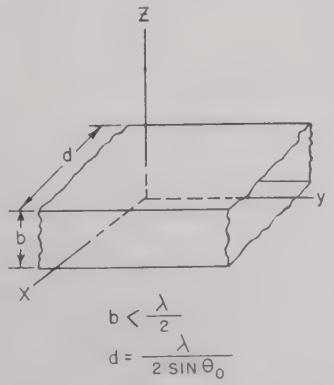

Fig. 2

We will consider in detail a configuration of conducting sheets which consists in part of a rectangular waveguide whose walls fit into the field as specified (Fig. 2) Only the case in which the waveguide is cut off for all modes except the TE_{01} will be considered. This restric-

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tion specifies that the "narrow" faces of the waveguide lie along two adjacent null planes and that $\theta_0 > 30°$. This value of θ_0 corresponds to cutoff conditions for the TE_{02} mode. We will specify, further, the form of the waveguide to be considered by stating that all four of its boundary walls are continuous for all points to the left of the origin (i.e. for $y<0$). For $y>0$ on the other hand, the waveguide walls may extend any desired distance and may be arbitrarily separated or perforated as long as the conducting portions remain in the appropriate null planes. There may be present, in addition, any number of conducting sheets occupying any portions of the other null planes. Fig. 3 shows some examples of allowable systems. The waveguide and its array of appropriately located conducting sheets may now be regarded as a receiving antenna receiving signals simultaneously from the two sources a and b and feeding them into the infinitely long waveguide to the left of the origin. Although the procedure followed in the foregoing steps fixed the angle θ_0 simply by the choice of location of the two sources, we are ultimately interested in the radiation properties of a waveguide with given dimensions at a specified frequency. For this reason, θ_0 should be considered as a dependent rather than an independent variable (i.e. $\theta_0 = \sin^{-1}(\lambda/2d)$).

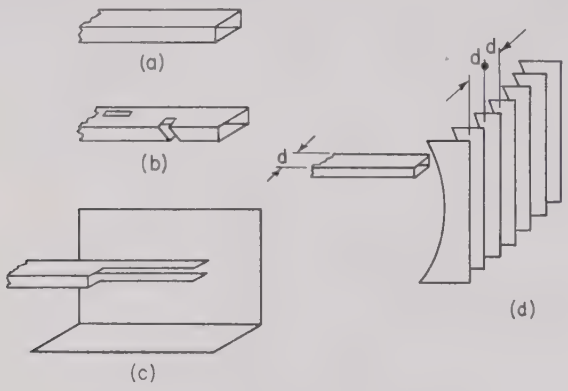

Fig. 3

III. Gain Calculations

If one of the two sources is removed, the problem is no longer a simple one for which the solution is the same with or without conductors. To find the fields in this case would require the solution of a boundary-value problem of considerable difficulty even for the simplest configurations included in the general description above. By virtue of the restriction that the waveguide will propagate only the TE_{01} mode, however, we may at least write the form of the electric field for points inside the continuous portion of the waveguide which are sufficiently far removed from the origin that all the higher-order modes are essentially damped out. The electric field in a TE_{01} wave traveling to the left is of exactly the same form as the field given by (1) so we may write for the field due to source a alone

$$E_a = h_a E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0}. \tag{2}$$

The complex factor of proportionality h_a relates the amplitude and phase of the TE_{01} wave inside the waveguide (referred to the origin) to the field E_0 which would be produced at the origin by source a if all the conductors were absent. Similarly, for the field due to source b alone,

$$E_b = h_b E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0}. \tag{3}$$

Since, by the principle of superposition, the sum of these must equal the field E_z given by (1) it follows that

$$h_a + h_b = 2. \tag{4}$$

In the case of the general configuration of conductors, subject only to the conditions outlined above, we can proceed on simple grounds no further than (4). There are, however, two special classes of antennas contained within the scope of this general configuration which are of considerable interest and which allow additional development. These are:

(i) Systems having physical symmetry about the plane $x=0$. For this class, it follows immediately that

$$h_a = h_b = 1. \tag{5}$$

(ii) Systems for which it is known from measurements or from other considerations that either h_a or h_b = zero. This would be the case if the z component of the radiation pattern were zero in the direction of one of the two sources (such as would be expected, for example, with the antenna shown in Fig. 3(c)). For antennas of this type

$$\begin{aligned} h_a &= 2 \\ h_b &= 0. \end{aligned} \tag{6}$$

Proceeding with class (i) antennas, we may substitute from (5) into (2) and (3) to get

$$E_a = E_b = E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0}. \tag{7}$$

Either of the sources thus produces a TE_{01} wave traveling to the left of the form given by (7). The power abstracted from the incident field due to either source by the receiving antenna may now be calculated using the well-known expressions developed by integrating the Poynting vector over a cross section of the waveguide.[1,2] This calculation yields

$$P_{\theta_0} = \frac{E_0^2 b l \sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{2\eta}. \tag{8}$$

where $\eta = \sqrt{\mu_0/\epsilon_0}$, b and d are the transverse dimensions of the waveguide and the subscript θ_0 indicates that a

[1] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand Co., Inc., New York, N. Y., 1943.
[2] S. Ramo and J. R. Whinnery, "Fields and Waves in Modern Radio," John Wiley and Sons, New York, N. Y., 1944.

line connecting the origin and the distant source makes this angle with the waveguide axis.

One of the fundamental parameters characterizing the operation of an antenna is the receiving cross section.[3] This quantity is defined for a receiving antenna upon which a plane wave is incident by the equation

$$A\frac{E_0^2}{\eta} = P' \tag{9}$$

where

A = receiving cross section
E_0 = amplitude of electric field in incident wave (rms)
P' = available power, or power delivered to a termination which provides a conjugate match to the antenna impedance.

The receiving antenna may be represented by an equivalent circuit (Fig. 4) in which the waveguide is replaced by a transmission line and the antenna impedance or equivalent generator impedance is specified in terms of the reflection coefficient Γ_0 (referred to plane $y=0$) which would be present on the waveguide if the

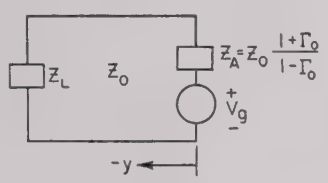

Fig. 4

antenna system were transmitting. The conditions under which P_{θ_0} was calculated correspond to the case $Z_L = Z_0$ in the equivalent circuit. A straightforward analysis of the circuit shows that this value of power is related to the available power by the expression

$$P_{\theta_0}' = \frac{P_{\theta_0}}{1 - |\Gamma_0|^2}. \tag{10}$$

Combining (8), (9), and (10) yields for this antenna

$$A_{\theta_0} = \frac{bd\sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{2(1 - |\Gamma_0|^2)}. \tag{11}$$

It is of interest to note that the numerator of this expression is the projected area of a cross section of the waveguide on a wave front of the incident plane wave.

The receiving cross section is related to the power gain through a simple factor of proportionality[3]

$$G = \frac{4\pi}{\lambda^2}A \tag{12}$$

where G is the power gain over an isotropic radiator in the direction from which the incident plane wave arrives to give the corresponding value of A. Combining (11) and (12), we obtain the expression

$$G_{\theta_0} = \frac{2\pi bd\sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{\lambda^2(1 - |\Gamma_0|^2)} \tag{13}$$

which gives the gain of the symmetrical antenna in the direction θ_0 in terms of the physical dimensions of the waveguide and the reflection coefficient in the waveguide when the system is operating as a transmitting antenna.

For class (ii) antennas, a similar analysis using (6) instead of (5) yields

$$G_{\theta_0} = \frac{8\pi bd\sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{\lambda^2(1 - |\Gamma_0|^2)}. \tag{14}$$

It should be remarked that (13) and (14) apply only to the z components of electric field in the appropriate directions θ_0. Symmetry arguments show that there will be only a z component of electric field produced by antennas having physical symmetry about the plane $z=0$. but that, in general, there may be x and y components also.

These relationships have been developed for the idealized problem of antennas being fed through waveguides of infinite length. At this point, it is of interest to consider briefly the manner in which the results would be modified in the more practical case involving a waveguide of finite length. If, in the receiving case with both sources operating, the waveguide were closed with a conducting plate a finite distance to the left of the origin and a matched termination were placed inside the waveguide near the closed end, the TE_{01} waves inside the remaining portion of the waveguide could still travel only to the left. The form of the fields on the outside of the waveguide, on the other hand, would have to be modified by a correction term to account for the diffraction of the incident waves about the closed end. The main part of this correction term would take the form of a perturbation field spreading out from the location of the closed end. The amount by which the amplitude of the TE_{01} wave inside the waveguide would be changed from the value calculated above, would depend on the amount by which this perturbation field modified the fields in the vicinity of the open part of the waveguide. It is reasonable to assume that this modification could be made negligibly small by moving the closed end sufficiently far from the origin. It is thus concluded that the results calculated above should apply to practical systems with long waveguides, but no attempt is made to specify limits in numerical terms.

IV. Some Additional Properties

Consider, now, a configuration of conductors meeting the requirements of the general case given above, but with the sources moved to positions c and d (Fig. 5).

[3] H. D. Friis and W. D. Lewis, "Radar antennas," *Bell Sys. Tech. Jour.*, vol. 26, pp. 219–318; April, 1947.

As before, the waveguide is continuous to the left of the origin, but in this case, it extends only a finite distance to the left, ending in an open termination. Proceeding as before, the total electric field in this problem is shown to be

$$E_z = 2E_0 \cos (kx \sin \theta_0) e^{-jky\cos\theta_0}. \tag{15}$$

Inside the waveguide, this field constitutes a TE_{01} wave moving to the right.

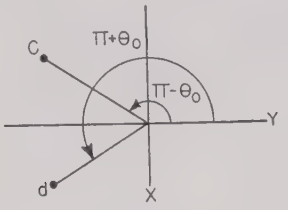

Fig. 5

We will now close the left end of the waveguide with a shorting plate and place a matched termination inside the waveguide near this end. In addition, we will install a source of energy near this terminated end and adjust its amplitude and phase so that its direct wave (traveling to the right in the waveguide) is of exactly the form given by (15). Since the incident waves from sources c and d and the incident TE_{01} wave reach the antenna end of the waveguide with the same relative amplitudes and phase as they had when the remote end of the waveguide was open (neglecting the perturbation field as discussed in the preceding section) it follows that (15) still gives the electric field both inside and outside the waveguide. This field may be interpreted as the superposition of the individual fields due to the two external sources c and d and the source inside the waveguide.

The TE_{01} waves excited in the waveguide by the external sources can travel only to the left since energy can enter the waveguide only at the antenna end, and the matched termination precludes the possibility of reflected waves being set up. The fields due to these sources, therefore, are of the form

$$E_c = h_c E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0}, \tag{16}$$

$$E_d = h_d E_0 \cos (kx \sin \theta_0) e^{jky\cos\theta_0}. \tag{17}$$

The internal source, on the other hand, will produce waves in both directions, a direct wave traveling to the right and a reflected wave traveling to the left. Designating these fields by the subscript e we have

$$E_e = 2E_0 \cos (kx \sin \theta_0) \{e^{-jky\cos\theta_0} + \Gamma_0 e^{+jky\cos\theta_0}\} \tag{18}$$

where the reflection coefficient Γ_0 is again referred to the plane $y=0$. Equation the sum $E_c+E_d+E_e$ to the field E_z given by (15) leads to the condition

$$h_c + h_d + 2\Gamma_0 = 0. \tag{19}$$

Solving for Γ_0 and replacing the numerical factor 2 by its equivalent from (4) yields

$$\Gamma_0 = -\frac{h_c + h_d}{h_a + h_b}. \tag{20}$$

The h's have been introduced as constants of the receiving antenna. A simple application of reciprocity allows (20) to be re-stated in terms of the distant fields produced by the waveguide antenna when transmitting. Thus

$$\Gamma_0 = -\frac{E_{zc} + E_{zd}}{E_{za} + E_{zb}} \tag{21}$$

where the fields E_z are measured (in amplitude and phase) at the points previously occupied by the distant sources. For class (i) antennas, (21) reduces to

$$\Gamma_0 = -\frac{E_{zc}}{E_{za}}. \tag{22}$$

Thus a measurement of the reflection coefficient inside the waveguide specifies the ratio of the radiation fields in these directions.

Combining the information in (22) with that in (13) allows evaluation of the gain in the direction of point c.

$$G_{\pi-\theta_0} = \frac{2\pi bd\sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{\lambda^2\left(\frac{1}{|\Gamma_0|^2} - 1\right)}. \tag{23}$$

V. Application to Another Type of Waveguide Antenna

Returning now to free-space conditions, let us consider the fields produced when all four sources, a, b, c, and d are operating simultaneously. If the common phase of c and d differs from that of a and b by π, the total electric field may be written as the field given by (1) minus that given by (15)

$$E_z = j4E_0 \cos (kx \sin \theta_0) \sin (ky \cos \theta_0). \tag{24}$$

This field has the same null planes as the fields considered previously plus another set occurring at the planes

$$y = \frac{m\lambda}{2 \cos \theta_0}$$

where m may have integral values (including zero).

We will again consider antennas fed by a single waveguide of finite length with continuous walls to the left of the origin. A few examples of configurations fitting into this system of null planes are shown in Fig. 6.

In this case, the left end of the waveguide may be closed with a shorting plate without the appearance of correction terms in the equations for the fields, provided the plate is located on one of the new set of null planes.

It is of interest to note, in passing, that the null planes now available allow the construction of completely closed systems such as that shown in Fig. 6(d).

For such systems, the outside fields must still be given by (24), but the inside region is completely isolated from the external sources, and hence the fields in this region are no longer related to the outside fields. If a hole of any size is cut anywhere in the conducting boundary, however, it may be argued that since (24) is a solution, it is the only solution and is valid in both regions.

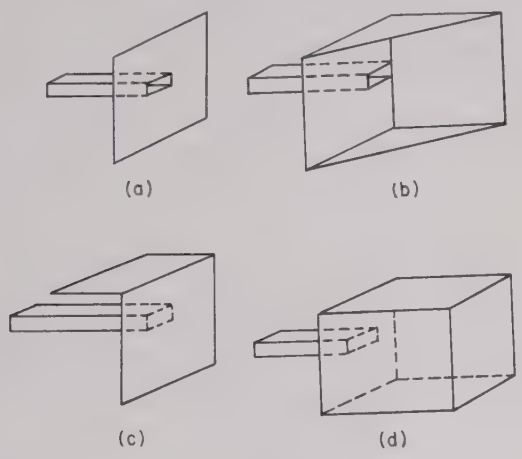

Fig. 6

Returning to the antenna problem, it is seen that the waves inside the waveguide now consist of one TE_{01} wave traveling to the right and another of equal amplitude traveling to the left with relative phases such that cancellation occurs at $y=0$. This condition is not altered if we again place a matched termination and a source of energy in the waveguide near the left end with the amplitude and phase of the source adjusted so that its direct wave (traveling right) is of the proper form (i.e. the negative of (15)). The wave components present in this case are summarized in the diagram of Fig. 7. The

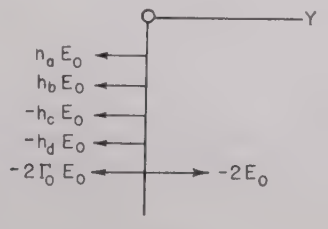

Fig. 7

only wave traveling to the right is the direct wave due to the internal source since all components entering at the antenna end are absorbed in the matched termination at the left end. Since the total field must vanish for $y=0$ in accordance with (24), we have the result

$$h_a + h_b - h_c - h_d = 2(1 + \Gamma_0). \tag{25}$$

For systems whose radiation patterns have zeros in the direction of sources c and d such as might be the case, for example, with the antenna of Fig. 6(a), (25) is simplified in that h_c and h_d are both zero. If, in addition, the antenna is of the symmetrical type (class (i)), (25) reduces to

$$h_a = h_b = 1 + \Gamma_0. \tag{26}$$

Proceeding as in the previous gain calculation we obtain

$$G_{\theta_0} = \frac{2\,|\,1 + \Gamma_0\,|^2 \pi bd \sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{\lambda^2(1 - |\,\Gamma_0\,|^2)}. \tag{27}$$

In this case, both the magnitude and phase of Γ_0 must be known in order to evaluate G_{θ_0}. The reflection coefficient is again referred to the plane $y=0$ which is automatically fixed in a physical system as the location of one of the conducting sheets normal to the axis of the waveguide (or a parallel plane spaced $m\lambda/2 \cos\theta_0$ from such a conducting sheet). For antennas having radiation-pattern zeros in three of the four directions of interest so that $h_b=h_c=h_d=0$ (Fig. 6(b)), the gain in the remaining direction becomes

$$G_{\theta_0} = \frac{8\,|\,1 + \Gamma_0\,|^2 \pi bd \sqrt{1 - \left(\frac{\lambda}{2d}\right)^2}}{\lambda^2(1 - |\,\Gamma_0\,|^2)}. \tag{28}$$

VI. Conclusions

Quantitative relationships between the pattern and impedance characteristics of various types of waveguide-excited radiators have been established. The results obtained are exact only for systems employing ideal conductors of the type assumed in the analysis. It appears justified, however, to conclude that these results will be good approximations for practical systems using good conductors whose thickness is small compared with the dimensions of the openings in the waveguide. Slotted-waveguide radiators (Fig. 3(b)) would not meet this requirement, in general, since the slot width in such antennas is ordinarily comparable with the wall thickness. The system shown in Fig. 6(a), on the other hand, meets the requirements quite well. In this case, the ends of the waveguide walls simply form part of the large sheet in which the waveguide terminates, so the "opening" in the system has the dimensions of this transverse sheet. It is believed that antennas of this type and of the type shown in Fig. 6(b) might find application as gain standards. Some development work on standard-gain antennas employing these principles will be undertaken at this laboratory in the near future.

Certain properties of the radiation patterns and the radiation resistance of loop and dipole elements near flat-plate and corner reflectors may be deduced by a procedure similar to that used above.

Acknowledgment

The author wishes to express his thanks to the other members of the research staff of the University of California Antenna Laboratory, and particularly to Samuel Silver and E. J. Moore, for the encouragement and counsel given during the preparation of this paper.

A Note on Filter-Type Traveling-Wave Amplifiers*

J. R. PIERCE†, FELLOW, IRE, AND NELSON WAX‡

Summary—A small-signal analysis of systems in which an electron beam interacts with a circuit composed of discrete filter elements is given here. The effects of a line beam interacting with a series of gaps, which are capacitive elements of a filter structure, are calculated, and it is shown that an admittance can be introduced which arises from the presence of the electrons. This admittance is in parallel with the gap capacitance, and thus will alter the propagation factor of the filter circuit. It is shown that traveling-wave solutions exist for the combination of electron beam and filter circuit, and that there is a solution which has a positive real part, indicating that gain will be exhibited.

TRAVELING-WAVE amplifiers with high efficiencies and large gains might be obtained if one could increase greatly the impedance of the helices used; unfortunately, the practicable range of helix impedance is relatively small, and one is thus led to a consideration of different kinds of circuits. This note presents the results of a small-signal analysis of iterated structures coupled to an electron beam; it is shown that traveling-wave solutions exist for such systems, and that the gain of the system will increase with increasing circuit impedance.[1] The main disadvantage in using filter-type circuits of high impedance, rather than helices, would be the narrower bandwidths of the former.

The system to be considered is shown in Fig. 1. A source of electromagnetic energy (not shown in the figure) is delivering power to a load, which terminates the lossless circuit in its characteristic impedance. The direction of propagation of energy is to the right, when the electrons are absent; i.e., the group velocity of the "undisturbed circuit wave" is positive. The average motion of the electrons is to the right; the electron stream is coupled capacitively to the circuit only at the gaps shown, which are similar capacitors in corresponding branches of every filter section.

The following assumptions and restrictions hold throughout this work:

1. Space-charge effects are neglected.
2. The differences of potential are never more than a few kilovolts, and, therefore, the magnetic effects of the moving electrons may be ignored.
3. The time taken for an electron to cross any of the gaps is small compared with the period of the ac oscillations.
4. The ac components of voltage, current, etc., are so small compared to their dc values that products and squares of ac quantities may be neglected.

Notation: Circuit quantities will be in upper-case letters, those for the electron stream in lower-case letters. dc quantities will have the subscript zero, and ac quantities (with the factor $e^{j\omega t}$ omitted) will have the subscripts appropriate to the gap considered.

Units: Mks units are used.

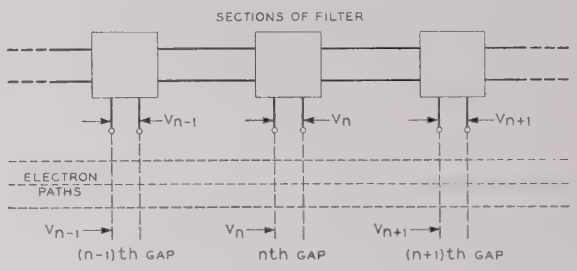

Fig. 1—A schematic representation of the system considered is shown here.

Let v_n be the ac component of velocity of an electron just before it crosses the n^{th} gap, and V_n the ac voltage across the n^{th} gap. Then v_{n+1} will be related to v_n and V_n by[1]

$$v_{n+1} = \left[v_n + \eta \frac{M}{u_0} V_n \right] e^{-j\theta} \tag{1}$$

where

η = the ratio of the charge of the electron to its mass
u_0 = the average electron velocity
M = the modulation coefficient
θ = the transit angle,[1] $j = \sqrt{-1}$
$e = 2.718\ldots$

If a traveling-wave solution exists, then

$$v_{n+1} = v_n e^{\Gamma}, \tag{2}$$

with similar equations for the other ac quantities; Γ is the propagation factor of the system.

The ac component of the convection current at the $(n+1)$st gap, i_{n+1}, is given, in terms of i_n, by[2]

$$i_{n+1} = i_n e^{\Gamma} = \left[i_n - j\theta \left(\frac{v_n}{u_0} + \eta \frac{M}{u_0^2} V_n \right) i_0 \right] e^{-j\theta} \tag{3}$$

where i_0 is the dc convection current.

The ac component of velocity, v_n, may be eliminated from (1), (2), and (3); then one obtains

$$i_n = -\frac{j\theta M i_0 V_n}{2V_0} \frac{e^{\Gamma + j\theta}}{(e^{\Gamma + j\theta} - 1)^2} \tag{4}$$

with the dc voltage $V_0 = u_0^2/2\eta$.

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[1] Some similar work is to be found in Andre Blanc-Laprene and Pierre Sapostelle, "Contribution a L'Etude des Amplifications a Ondes Progressives," *Ann. de Telecommunications*, vol. 1, no. 12, pp. 283–302; December, 1946.

[2] J. R. Pierce and W. G. Shepherd, "Reflex oscillators," *Bell Sys. Tech. Jour.*, vol. 26, pp. 460–681; July, 1947.

The convection current i_n will induce a current $-Mi_n$ in the circuit. One may thus introduce an admittance, y_e, which arises from the presence of the electrons,

$$y_e = -\frac{Mi_n}{V_n} = \frac{j\theta i_0 M^2}{2V_0} \frac{e^{\Gamma+j\theta}}{(e^{\Gamma+j\theta}-1)^2}, \tag{5}$$

is in parallel with the gap admittance, and is small compared to it.

Let the propagation factor for the filter, within the pass band, be $-j\beta$ when there are no electrons present. Then

$$\cosh(-j\beta) = 1 + \frac{Y_2}{2Y_1} \tag{6}$$

where Y_1 and Y_2 are the admittances of the series and shunt arms of the filter section, respectively.

One defines the function $F(y_e)$ by

$$F(y_e) = \frac{Y_2(y_e)}{2Y_1} \tag{7}$$

or

$$F(y_e) = \frac{Y_2}{2Y_1(y_e)}$$

where the admittance y_e has been added to the gap admittance appropriately, in either the shunt or series arm of the filter, respectively. The parentheses indicate functional dependence.

One may expand $F(y_e)$ in a Maclaurin series and obtain

$$F(y_e) = F(0) + F'(0)y_e + \cdots \tag{8}$$

where $F(0) = Y_2/2Y_1$, $F'(0)$ etc., depend on the circuit used. Two simple examples of it are given below. The primes denote differentiation with respect to y_e.

The propagation factor of the system (circuit plus electron stream) is given by

$$\cosh\Gamma = 1 + F(y_e). \tag{9}$$

One obtains

$$\cosh\Gamma - \cos\beta = j\theta DF'(0) \frac{e^{\Gamma+j\theta}}{(e^{\Gamma+j\theta}-1)^2} \tag{10}$$

by combining (5), (6), (8), and (9), and using the first two terms in the expansion for $F(y_e)$.

$$D \equiv \frac{M^2 i_0}{2V_0}.$$

Let $\Gamma = -j(\beta+\gamma)$. One assumes here that $|\gamma| \ll |\beta|$; i.e., that the change in propagation factor arising from the presence of the electrons is small when the signal is small. This assumption is not necessary, though it is convenient, and the exact equations are given in the Appendix.

Equation (10) then becomes

$$\frac{\gamma^4}{4}[\cos(2\beta-\theta)+\cos\theta] + \gamma^3\sin(2\beta-\theta) - \frac{\gamma^2}{2}[\cos\theta + 2\cos\beta - 3\cos(2\beta-\theta)] + 2\gamma\sin\beta[1-\cos(\beta-\theta)] = j\theta DF'(0). \tag{11}$$

The approximations $\cosh\gamma \doteq 1+\gamma^2/2$, $\sinh\gamma \doteq \gamma$ have been used.

The nature of the roots of (11) is dependent on the function $F'(0)$. Two cases are considered: (a) the series arm, or (b) the shunt arm of the filter is the gap capacitance.

For case (a)

$$F(y_e) = \frac{Y_2}{2(Y_1+y_e)} \tag{12}$$

with

$$F'(0) = -\frac{Y_2}{2Y_1^2} = -\frac{Z_1^2}{2Z_2}. \tag{13}$$

For case (b)

$$F(y_e) = \frac{Y_2+y_e}{2Y_1} \tag{14}$$

with

$$F'(0) = \frac{1}{2Y_1} = \frac{Z_1}{2}. \tag{15}$$

In either case $F'(0) = jX$ where X is a real quantity (positive for case (b) and negative for case (a)) when the filter is composed of pure reactances and the region of operation is within its pass band. It is particularly noteworthy that under these conditions, filters with inductive series arms have $0 \leqq \beta \leqq \pi$ (case b) and those with capacitive series arms have $-\pi \leqq \beta \leqq 0$ (case a). β increases monotonically with frequency for both case (a) and case (b). Furthermore, the direction of propagation of the wave cannot be inferred from the phase velocity; one must resort to the group velocity.

Let V_g be the group velocity, v_p the phase velocity, $\omega = 2\pi f$, and $Im\Gamma$ the imaginary part of Γ.

The relationship between V_g, v_p, and ω is given by

$$\frac{1}{V_g} = \frac{1}{v_p} - \frac{\omega}{v_p^2}\frac{dv_p}{d\omega}; \tag{16}$$

since $v_p = -\omega/Im\Gamma$ one obtains

$$\frac{1}{V_g} = -\frac{dIm\Gamma}{d\omega} = -\frac{dIm\Gamma}{d\beta}\frac{d\beta}{d\omega}. \tag{17}$$

The wave will be propagated to the right, in the direction of the average motion of the electrons, if the imaginary part of Γ is negative, and increasing with β (or ω), or positive, and decreasing with β.

Returning to (11) and using the expressions given above for $F'(0)$ one has

$$\frac{\gamma^4}{4}\left[\cos(2\beta-\theta)+\cos\theta\right]+\gamma^3\sin(2\beta-\theta)+\frac{\gamma^2}{2}\left[\cos\theta+2\cos\beta-3\cos(2\beta-\theta)\right]+2\gamma\sin\beta\left[1-\cos(\beta-\theta)\right]+\theta DX=0. \quad (18)$$

Equation (18) may be simplified in an important special case, namely, when $\beta=\theta+2m\pi$ (case b), m an integer. This corresponds to linear phase shift with frequency, since the transit angle θ is linear with frequency, for constant dc voltage. One obtains

$$\frac{\gamma^4}{2}\cos\theta+\gamma^3\sin\theta+\theta DX=0. \quad (19)$$

X is a positive quantity here.

Synchronism between the undisturbed circuit wave (i.e. when the electrons are absent) and the average motion of the electrons is given, for case (a), by $\theta=\beta=2m\pi$ (β negative, m an integer). Equation (19) still holds, with X now negative. As β varies from $-\pi$ to 0 in the pass band, $\sin\theta$ will be negative in (19) as well.

The definition of γ, $\Gamma=-j(\beta+\gamma)$, indicates that gain will occur for the system if there is a root of (18) or (19) which has an imaginary part that is positive, and a real part that satisfies the condition that V_0 be positive. The first condition assures the existence of an increasing wave, and the second, that this wave shall be propagated to the right.

A circuit wave with a negative group velocity (propagation to the left, contrary to the electron motion) may appear to have a positive phase velocity equal to the electron velocity. It seems physically unreasonable that the over-all wave resulting when the electrons are present could have a negative group velocity and increase in traveling to the left; this would imply a bunching of the electrons to give up power in anticipation of the arrival of the wave.

The correspondence between discrete circuits, which have been treated here, and continuous circuits, which Pierce[3] has discussed in considerable detail, may be demonstrated by considering the limiting form of the filter circuit as the length of a section goes to zero, and the number of sections becomes infinite. It is found that the equation for the discrete case is indistinguishable from that for a corresponding continuous case if $|\delta/2|\cot\beta\ll 1$.

[3] J. R. Pierce, "Theory of the beam-type traveling-wave tube," Proc. I.R.E., vol. 35, pp. 111–123; February, 1947.

To show the variation of gain and phase of the increasing wave with drift angle θ, the roots of (19) have been obtained for the following sets of numbers: $M=1$, $V_0=1000$ volts, $i_0=0.001$ amperes, $F'(0)=\pm j$ 2,000 ohms. The real and imaginary parts of the root satisfying the above conditions for system gain are shown in Figs. 2 and 3, as functions of θ and β. Two of the other

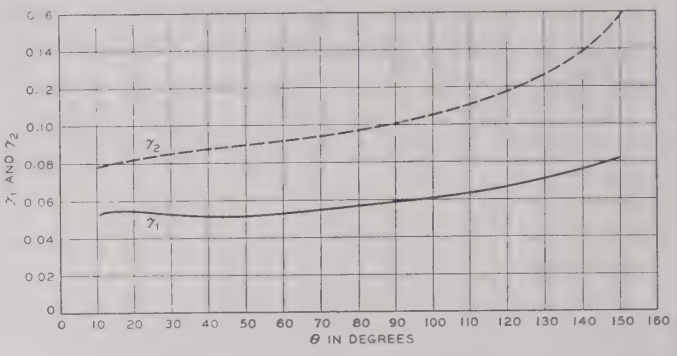

Fig. 2—The real part of the root γ_1 pertaining to phase and the imaginary part of the root γ_2 giving gain, shown as functions of θ. The change per section of the ac quantities is $\exp[-j(\beta+\gamma_1)+\gamma_2]$. The equation which was solved was $\gamma^4/2\cos\theta+\gamma^3\sin 0+0.001\theta=0$, $\beta=\theta$ (case b).

roots were real, in each case, indicating a shift in phase from the undisturbed circuit wave, and the remaining one was the complex conjugate of the one shown in the figures, introducing attenuation rather than gain. It should be noted that $F'(0)$ can be expressed in terms of the characteristic impedance and phase shift of the filter, if desired, and will not be, in general, a constant. In these calculations, $F'(0)$ was taken as a constant, for simplicity. The regions where this assumption is most likely to break down, namely, near the edges of the pass band, were omitted in the figures.

A check on the accuracy of the roots obtained is given in the Appendix.

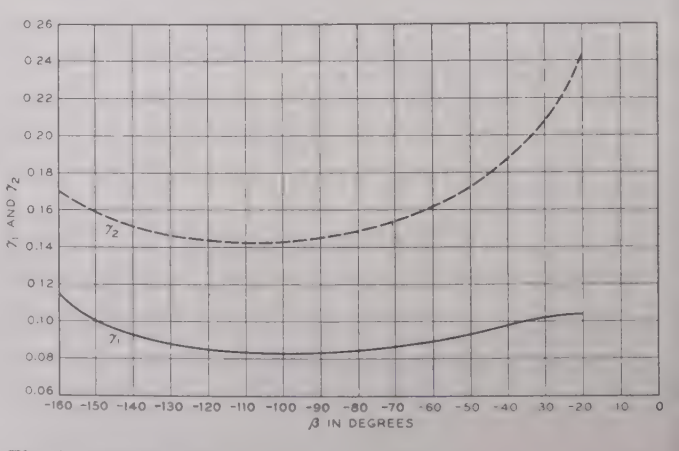

Fig. 3—The real part of the root γ_1 pertaining to phase and the imaginary part of the root γ_2 giving gain, shown as functions of β. The change per section of the ac quantities is given by $\exp[-j(\beta+\gamma_1)+\gamma_2]$. The equation which was solved was, $\gamma^4/2\cos\beta+\gamma^3\sin\beta-0.001\theta=0$, $\theta-\beta=2\pi$ (case a).

The authors thank their colleague, Miss Mary E. Moore, for her efficient performance of all the numerical calculations and her care in checking many of the algebraic details.

Appendix

It was assumed, in deriving (11) from (10), that $|\gamma| \ll |\beta|$ where $\Gamma = -j(\beta+\gamma)$. This approximation is not invoked here, and the exact small-signal equations are obtained.

Let $e^{\Gamma} = \rho e^{-j\Phi}$. If this substitution is made in (10) then the pair of simultaneous quadratic equations with real coefficients

$$\begin{aligned}&\rho^4 \cos(4\Phi - \theta) - 2\rho^3[\cos 3\Phi + \cos(3\Phi - \theta)\cos\beta]\\&\quad + \rho^2[\cos(2\Phi + \theta) + \cos(2\Phi - \theta)\\&\quad + 4\cos 2\Phi \cos\beta + 2\theta DX \cos 2\Phi]\\&\quad - 2\rho[\cos\Phi + \cos(\Phi + \theta)\cos\beta] + \cos\theta = 0 \qquad (20)\end{aligned}$$

and

$$\begin{aligned}&\rho^4 \sin(4\Phi - \theta) - 2\rho^3[\sin 3\Phi + \sin(3\Phi - \theta)\cos\beta]\\&\quad + \rho^2[\sin(2\Phi + \theta) + \sin(2\Phi - \theta)\\&\quad + 4\sin 2\Phi \cos\beta + 2\theta DX \sin 2\Phi]\\&\quad - 2\rho[\sin\Phi + \sin(\Phi + \theta)\cos\beta] + \sin\theta = 0 \qquad (21)\end{aligned}$$

are obtained by expanding and separating real and imaginary quantities. The substitution in (10) shows directly that there are four waves.

Gain will occur for the system when $\rho > 1$ and when the direction of propagation is to the right (a positive group velocity). The use of (16) with $v_p = \omega/\Phi$ yields

$$\frac{1}{V_g} = \frac{d\Phi}{d\omega} = \frac{d\Phi}{d\beta}\frac{d\beta}{d\omega}. \qquad (22)$$

As before, V_g will be positive when $d\Phi/d\beta$ is positive.

In the body of this paper, the equation $\Gamma = -j(\beta+\gamma)$ was used; here the substitution $e^{\Gamma} = \rho e^{-j\Phi}$ is made. The connection between the two sets of quantities is, for $\gamma = \gamma_1 + j\gamma_2$,

$$\left.\begin{aligned}e^{\gamma_2} &= \rho\\ \beta + \gamma_1 &= \Phi\end{aligned}\right\}. \qquad (23)$$

The roots of equation (18) may be used, with the aid of equations (23), as a first approximation in the solution of equations (20) and (21).

The root of equations (20) and (21) which corresponds to the values shown in Fig. 2 at $\beta = \theta = \pi/2$, $DX = 0.001$, is $\rho = 1.08$, $\Phi = 1.63$; this yields, using (23), $\gamma_1 = 0.06$, $\gamma_2 = 0.078$. The values obtained from (19) are $\gamma = 0.058$, $\gamma_2 = 0.101$. Similarly when $\beta = -\pi/2$, $\theta = 3\pi/2$, $DX = -0.001$, (20) and (21) yield $\rho = 1.16$, $\Phi = -1.49$, giving $\gamma_1 = 0.08$, $\gamma_2 = 0.149$. The approximate root had $\gamma_1 = 0.084$, and $\gamma_2 = 0.145$. Thus the approximation is fairly good even for the relatively large value of X which was used.

Correction

W. W. Mumford, whose paper, "Directional Couplers," appeared on pages 160–165 of the February, 1947, issue of the Proceedings of the I.R.E., has called to the attention of the editors an error in Fig. 6, which appeared on page 163. The correct figure is presented herewith.

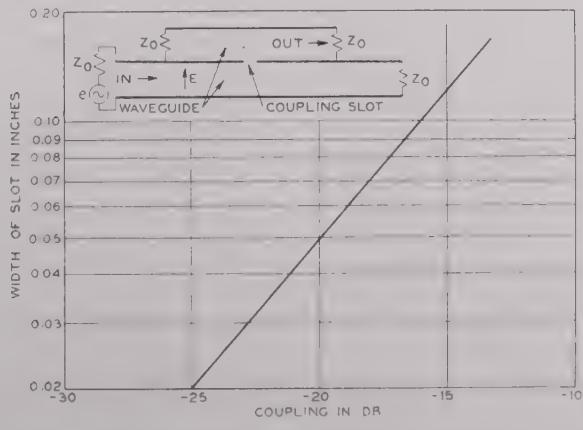

Fig. 6—Coupling ($10 \log_{10} P_{out}/P_{in}$) versus slot width for narrow slots across the wide face of 1-×2-inch rectangular waveguide. $\lambda_0 = 7.4$ centimeters. The wall thickness is 0.128 inch.

Note on Space-Charge Considerations in Test-Diode Design*

EDWARD A. COOMES†, SENIOR MEMBER, IRE, AND JAMES G. BUCK†

Summary—**A computation has been made of the conditions for choice of anode and cathode diameters in test diodes that will give the minimum variation in the slope of the space-charge line with small variations in tube geometry.**

THE EXPERIMENTAL development of microwave tubes usually brings about attempted correlations between tube performance and cathode quality, particularly when oxide cathodes are used. Such experiments indicate that many instabilities, such as certain types of moding and sparking in multiple-cavity magnetrons and loss of efficiency in coplaner triodes, may to a large extent be decreased by increasing the electron emitting capacity of the cathode.[1,2] While this cathode property has been ascertained in various ways which are often dependent upon measuring techniques available, an accurate and conservative measure of the intrinsic electron emission may be taken as that value of the cathode current density $I^{2/3}$ versus V plot at which the experimental points first deviate appreciably from the theoretical space charge line for the test tube which contains the cathode. If the interface plus coating resistance of the cathode is small, the emission I_0 taken at this point (see Fig. 1), which represents the maximum space-charge-limited current, corresponds to the primary emission with zero field at the cathode when held at its operating temperature. This point may be determined without recourse to considerations of the cathode characteristic in the Schottky region where phenomena may be varied and complicated. For example, if instead of I_0 in Fig. 1, I_A measured at an arbitrary anode voltage V_A were taken as the cathode emission, definite correlation between this quantity and microwave performance would be impossible.

The testing of experimental cathodes in diodes has been found useful both in the production of types needed for new tube developments and in deriving new fundamental information about the cathodes themselves.[1,3] This is particularly true when $I^{3/2}$ versus V plots of emission data were made the basis of interpretation. The usefulness of this procedure is contingent on the choice of anode and cathode dimensions which will allow the expectancy of an accurate fit of experimental data to a computed space-charge line. A good choice can be made, even though small deviations from theoretical geometry must be tolerated for practical reasons.

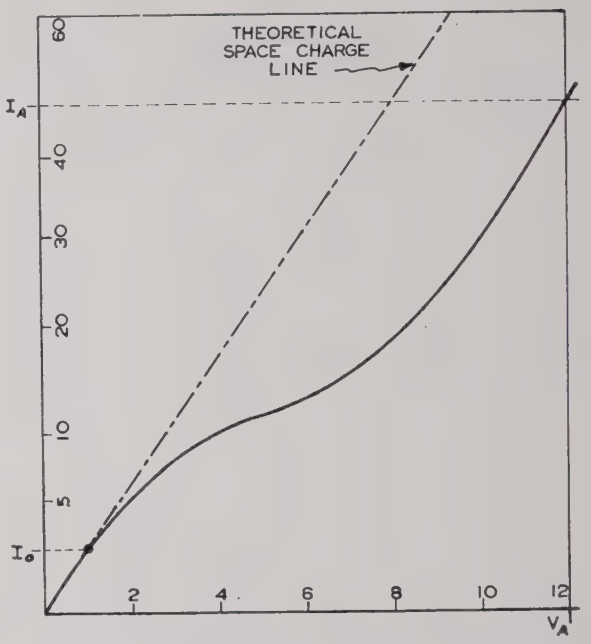

Fig. 1—Pulsed cathode emission characteristic of an oxide cathode in a cylindrical test diode. The current is plotted against anode voltage on $\frac{2}{3}$-power paper.

For test diodes of cylindrical symmetry the space-charge equations may be written

$$I = 2.33 \times 10^{-6} \frac{V^{3/2}}{r_c r_a \beta^2} \tag{1}$$

where

I = cathode current density in amperes/cm²
V = applied potential difference between anode and cathode in volts
r_a = anode radius in centimeters
r_c = cathode radius in centimeters.

The quantity β is a function of ratio of anode to cathode radius, $\sigma = r_a/r_c$, and is given by the series

$$\beta = \sum_0^\infty A_n (\ln \sigma)^n. \tag{2}$$

The A_n's have been given by Langmuir and Blodgett[4] as far as $n = 14$.

Equation (1) may be rewritten in the form

$$I^{2/3} = KV \tag{3}$$

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[1] E. A. Coomes, J. G. Buck, A. S. Eisenstein, and A. Fineman, "Alkaline Earth Oxide Cathodes for Pulsed Tubes," NDRC Report No. 14-933, March 30, 1946.

[2] M. A. Pomerantz, "Magnetron cathodes," PROC. I.R.E., vol. 34, pp. 903–910; November, 1946.

[3] E. A. Coomes, "The pulsed properties of oxide cathodes," *Jour. Appl. Phys.*, vol. 17, p. 647; August, 1946.

[4] I. Langmuir and K. B. Blodgett, "Currents limited by space charge between coaxial cylinders," *Phys. Rev.*, vol. 22, pp. 347–356; October, 1923.

so that space-charge-limited values of cathode current density plotted on an $I^{2/3}$ versus V plot will lie on a straight line of slope K, where

$$K = \text{const.} \left(\frac{1}{r_c r_a \beta^2} \right)^{2/3}. \tag{4}$$

The smallest change in K with tube dimensions would be obtained when K goes through a minimum; and a value of σ may be chosen to bring about that condition in the following manner.

$$\text{For} \qquad K = K_{\min}; \qquad \frac{dK}{d\sigma} = 0 \tag{5}$$

from which $\sigma_{\min}$ is the value of σ at which $K = K_{\min}$ may be obtained.

If values of K are plotted as a function of cathode diameter, the family of curves in Fig. 2 is obtained which indicates that the $K_{\min}$ is reached for $\sigma \simeq 3$.

If (5) is solved with accuracy to two decimal places $\sigma_{\min}$ has a value of 3.16.

ACKNOWLEDGMENT

The authors appreciate the helpful criticism of Henry F. Ivey and L. R. Bittman of the Westinghouse Electric Corporation, Bloomfield, N. J., on this problem.

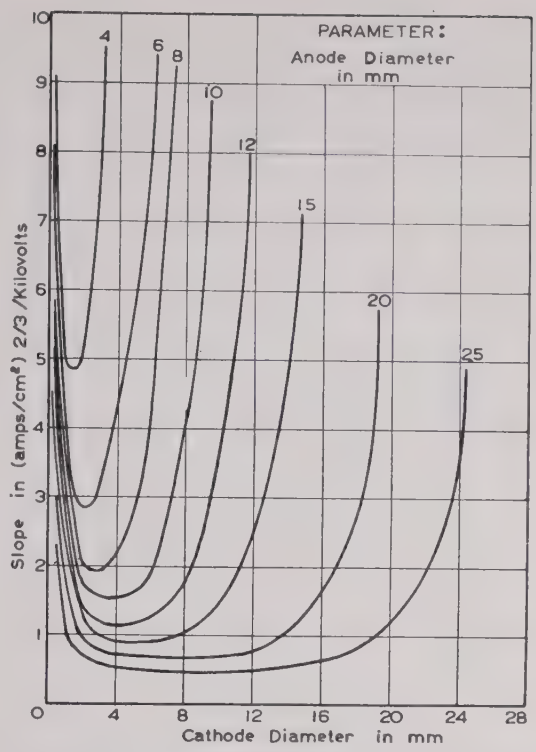

Fig. 2—The slope of the $I^{2/3}$ versus V line for the space-charge law for cylinders plotted against cathode diameter. Note that the ratio of anode to cathode radius for minimum change in slope is approximately 3.

The Synthesis of Electric Networks According to Prescribed Transient Conditions*

MORTON NADLER†, ASSOCIATE, IRE

Summary—**By use of the Laplace transform a network function may be obtained yielding a prescribed transient response. The procedure is based directly on the prescribed function of time, without consideration of amplitude or delay as a function of frequency. An example is given in which the Poisson-Stieltjes integral is employed for the physical realization of a network function which involves a transcendental term. In conclusion, certain questions are raised for further research in applied mathematics.**

I. The Problem

MODERN ELECTRONICS, with pulse modulation, television and radar, servomechanisms, etc., is very concerned with transient response. The usual approach in designing for good transient response is through "wide-band" amplifiers. This is frequently interpreted to mean uniform absolute magnitude of response over a sufficiently great frequency band. The empiric rule relates the required bandwidth to the rise time of the pulse. For instance, at the 1947 IRE National Convention, Lee[1] stated that "the frequency at which the response is 90 per cent of maximum must be 1/4 to 1/2 the reciprocal of the time required for the front of the pulse to attain 90 per cent of maximum amplitude, the figure of 1/4 to 1/2 depending on the circuit." For insurance, some have even proposed a bandwidth fully as great as the reciprocal of the rise time. But even this extreme "safety factor" is not enough to guarantee a satisfactory response. Nicolas[2] uses the simple example of the reactive all-pass lattice

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† Tesla, Prague, Czechoslovakia.

[1] Reuben Lee, "Frequency response," (Abstract), *Tele-Tech*, vol. 6, p. 55; May, 1947.

[2] P. Nicolas, "Filtres electriques, largeurs de bande et tamps d'etablissement," *Rev. Gen. Elec.*, p. 27; July 8, 1939.

filter section. The reciprocal of the bandwidth is zero. Nevertheless the rise time is finite.

The requirement that the time required for the signal to traverse the network be uniform over the pass band is well known. At the same Convention of the IRE DiToro[3,4] discussed this question and proposed a definition of phase bandwidth complementing the amplitude bandwidth usually meant by the unmodified term "bandwidth." He advised making the phase bandwidth several times wider than the amplitude bandwidth.

While many workers have given formulas relating phase response to attenuation characteristic and vice versa,[5,6] the sphere of application of these formulas is restricted. Furthermore, while the frequency response (steady-state) and the time response (transient) are directly related in the solution of the differential equations involved, yet previous methods based on these relations have been largely "cut-and-try."

Whiteman[7] anticipates the present work to some extent. However, this author completely neglects the possibility that the network function obtained may be nonrational, and still be physically realizable.

II. Fundamental Relations

A mathematical expression $\phi(p)$ describing an electrical network is called a network function. Formally, this function may be obtained by the substitution $p=j\omega$ in the impedance or admittance function of the network.[4] For the network function to correspond to a physically realizable, passive network, it is necessary and sufficient that (for two-terminal networks):

1. Zeros and poles either are real or occur in complex conjugate pairs.
2. The real and imaginary parts are, respectively, even and odd functions of p on the imaginary p-axis.
3. None of the zeros and poles may be found in the right half-plane, and zeros and poles on the imaginary p-axis must be simple.
4. The real component of the function cannot be negative on the imaginary p-axis.

Further conditions for four terminal networks are given by Bode.[5]

As stated above, the network function may be obtained in a formal manner from the impedance or admittance function with the substitution $p=j\omega$. But the same function may be obtained in the analysis of networks by means of the operational calculus rigorously based on the Fourier-Mellin theorem:[8]

Let $F(t)$ be an arbitrary function of the real variable t, with only a finite number of maxima and minima and discontinuities, and $F(t)=0$ for $t<0$. If

$$g(p) = p\int_0^\infty e^{-pt}F(t)dt \quad [R(p) > c > 0], \tag{1}$$

then

$$F(t) = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} e^{pt}\frac{g(p)}{p}\,dp, \tag{2}$$

provided

$$\int_0^\infty e^{-ct}F(t)dt$$

converges absolutely.

It should be noted that $g(p)/p$ is the Laplace transform of $F(t)$, written $L[F(t)]$.

In the analysis of the response $F_r(t)$ of a network $\phi(p)$ to an impressed driving function $F_d(t)$, one obtains the basic operational equation

$$L[F_r(t)] = \frac{L[F_d(t)]}{\phi(p)}. \tag{3}$$

This is an algebraic equation and *not* an integro-differential equation with p and $1/p$ written in place of the differential and integral operators. Therefore, we need only solve (3) for $\phi(p)$ to obtain

$$\phi(p) = \frac{L[F_d(t)]}{L[F_r(t)]} = \frac{g_d(t)}{g_r(t)}. \tag{4}$$

When $F_d(t)=H(t)$, the unit step function $[H(t)=0$ for $t<0$, $H(t)=1$, $t\geqq 0]$, then $g_d(p)=1$, $L[H(t)]=1/p$. We then obtain

$$\Phi(p) = g_r(p) \qquad \left(\Phi = \frac{1}{\phi}\right). \tag{4a}$$

If the desired network performance can be specified in terms of response to the unit function $H(t)$, the network function is given directly, bearing in mind that admittance and impedance have become interchanged; if in (4) ϕ represents admittance (impedance), then in (4a) Φ represents impedance (admittance). In the balance of the discussion we shall employ ϕ indifferently to represent the network function of (4) or (4a).

It is now necessary to determine whether ϕ is physically realizable. For two-terminal networks, the conditions given above are necessary and sufficient.

When ϕ is a rational function, we may employ the standard methods of network synthesis.[4] But, in general, ϕ will not be a rational function. In this case it is necessary to use some convenient approximation method, transforming ϕ into a convergent or asymptotically convergent rational function.

[3] M. J. DiToro, "Phase and amplitude distortion in linear networks," Proc. I.R.E., vol. 36, pp. 24–36; January, 1948.
[4] M. J. DiToro, "Network distortion," (Abstract) *Tele-Tech*, vol. 6, p. 55; May, 1947.
[5] Hendrik W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand, Inc., New York, N. Y., 1945.
[6] Wilhelm Cauer, "Das Poissonsche Integral und seine Anwendungen auf die Theorie der linearin Wechselstromschaltungen (Netzwerke)," *Elek. Nach. Tech.*, p. 17; January, 1940.
[7] R. A. Whiteman, "A contribution to the theory of network synthesis," Proc. I.R.E., vol. 30, pp. 244–245; May, 1942.
[8] Louis A. Pipes, "Applied Mathematics for Engineers and Physicists," McGraw-Hill Book Co., Inc., New York, N. Y. 1946.

For instance, ϕ may be expanded as an infinite product, realizable by the Foster reactance theorem, or which may further be transformed into partial fractions[9] or into a continued fraction.[10] The network function may be expanded as a Taylor series, which may then be realized as a network of lattice structures after a method of Wiener and Lee,[11] or which, again, may be transformed further, into a continued fraction.[10]

In the illustrative example of Section IV a transcendental ϕ is expressed as a Poisson-Stieltjes integral, which is expanded as a continued fraction.

III. The Poisson-Stieltjes Integral

Cauer gave a great deal of attention to the Poisson integral in the form of a Stieltjes integral. This integral has value in the physical realization of non-rational network functions.

Let $\phi(p)$ be a positive function, real for real p, regular and with positive real part in the right half-plane. Then[6]

$$\phi(p) = p\left[c + \int_0^\infty \frac{d\psi(x)}{p^2 + x}\right] \tag{5}$$

where

$$c = \lim_{p=\infty} \frac{\phi(p)}{p}\,; \quad d\psi(x) = \frac{R\{\phi(j\sqrt{x})\}}{\pi\sqrt{x}}\,dx. \tag{6}$$

Stieltjes has shown that if $\Psi(x)$ is an increasing function, with infinitely many points of growth, if the integrals

$$c_k = \int_0^\infty (-x)^{k-1} d\psi(x) \quad (k = 1, 2, 3, \cdots) \tag{7}$$

all exist, then the integral

$$\int_0^\infty \frac{d\psi(x)}{z + x} \tag{8}$$

may always be represented (except on the negative real axis) by a continued fraction of the form

$$\frac{1}{b_1 z} + \frac{1}{b_2} + \frac{1}{b_3 z} + \frac{1}{b_4} + \cdots \tag{9}$$

where the b_i are all positive.[10]

[Note: (9) is a concise notation for the more familiar

$$\cfrac{1}{b_1 z + \cfrac{1}{b_2 + \cfrac{1}{b_3 z + \cfrac{1}{b_4 + \cdots}}}}$$

with an infinite number of members.]

[9] Murray F. Gardner and John L. Barner, "Transients in Linear Systems," John Wiley and Sons, New York, N. Y., 1945.

[10] Oskar Perron, "Die Lehre von den Kettenbruchen," Leipzig, 1913.

[11] Norbert Wiener and Y. W. Lee, U. S. Patent numbers 2,024,900, 2,124,599, and 2,128,257.

Comparing (8) with (5), when the conditions for expressing (8) in the form of (9) are satisfied, (5) may be also expressed as a continued fraction, except for the imaginary p-axis. Fortunately, in network synthesis, it is the real p-axis which is employed ($p = j\omega$). Hence we may write

$$\phi(p) = p\left[C + \int_0^\infty \frac{d\psi(x)}{p^2 + x}\right] \tag{5}$$

$$= pC + \frac{p}{b_1 p^2} + \frac{1}{b_2} + \frac{1}{b_3 p^2} + \frac{1}{b_4} + \cdots \tag{10}$$

$$= pC + \frac{1}{b_1 p} + \frac{1}{b_2 p} + \frac{1}{b_3 p} + \frac{1}{b_4 p} + \cdots \tag{10a}$$

which is immediately realizable as a ladder network of pure reactance.

Following Perron,[10] if

$$\left.\begin{aligned} B_0(p) &= 1,\ B_1(p) = b_1 p^2,\ B_2(p) = b_1 b_2 p^2 + 1, \\ B_{2n+1}(p) &= b_{(2n+1)} p^2 B_{2n}(p) + B_{(2n-1)}(p) \\ B_{2n}(p) &= b_{2n} B_{(2n-1)}(p) + B_{(2n-2)}(p) \end{aligned}\right\} \tag{11}$$

then the b_i are obtained from

$$\frac{1}{b_{(2n+1)}} = \int_0^\infty [B_{2n}(j\sqrt{x})]^2 d\psi(x)$$

$$\frac{1}{b_{2n}} = \int_0^\infty \frac{1}{x}\,[B_{(2n-1)}(j\sqrt{x})]^2 d\psi(x).$$

Thus

$$\frac{1}{b_1} = \int_0^\infty d\psi(x) \qquad (n = 0)$$

$$B_1(p) = b_1 p^2$$

$$\frac{1}{b_2} = b_1^2 \int_0^\infty x\, d\psi(x) \qquad (n = 1)$$

$$B_2(p) = b_1 b_2 p^2 + 1$$

$$\frac{1}{b_3} = \int_0^\infty (1 - b_1 b_2 x)^2 d\psi(x) \qquad (n = 2)$$

etc.

IV. Illustrative Example

We wish to construct a single-stage amplifier whose response to the unit function is approximately the curve $(2G/\pi)Si(2t/a)$. Here, $2G/\pi$ is a proportionality constant relating the response to the gain G of the amplifier; Si is the "sine integral" function

$$\int_0^t \frac{\sin t}{t}\,dt$$

and t/a is the rise time in seconds. Si is the response of an "ideal" low-pass filter with linear phase response and zero attenuation within the pass band and 100 per cent

attenuation above the pass band. The function represents an oscillatory type of response (curve (a) in Fig. 1)

$$F_r(t) = \frac{2G}{\pi} Si \frac{2t}{a}; \qquad F_d(t) = g_m H(t). \tag{13}$$

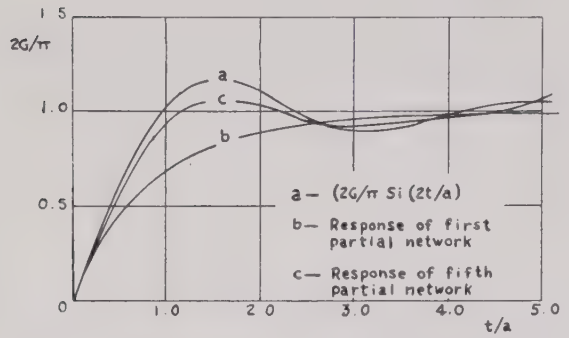


Fig. 1—Response of the first and fifth partial networks.

From a suitable table we obtain

$$g_r(t) = \frac{2G}{\pi} \cot^{-1} \frac{ap}{2}; \qquad g_d(t) = g_m. \tag{14}$$

This is real for real p, finite and with positive real part in the right half-plane, provided we take the principle value $0 \leqq \cot^{-1}(ap/2) \leqq \pi$. If we write $R_L = G/g_m$, we find the required *impedance*

$$\phi(p) = \frac{2R_L}{\pi} \cot^{-1} \frac{ap}{2}. \tag{15}$$

To represent (15) in the form of the Poisson-Stieltjes integral, we substitute in (5) and (6)

$$\left.\begin{aligned} C &= \lim_{p=\infty} \frac{2R_L}{\pi p} \cot^{-1} \frac{ap}{2} = 0 \\ d\psi(x) &= \frac{2R_L}{\pi^2 \sqrt{x}} R\left(\cot^{-1} \frac{aj\sqrt{x}}{2}\right) dx. \end{aligned}\right\} \tag{16}$$

But

$$\begin{aligned} R(\cot^{-1} jy) &= \frac{\pi}{2}; \qquad -1 < y \leqq 1 \\ &= 0; \qquad |y| > 1. \end{aligned}$$

Hence

$$\left.\begin{aligned} d\psi(x) &= \frac{R_L}{\pi\sqrt{x}} dx; \qquad x \leqq \frac{4}{a^2} \\ &= 0; \qquad x > \frac{4}{a^2}, \end{aligned}\right\} \tag{17}$$

and finally

$$\phi(p) = \frac{R_L p}{\pi} \int_0^{4/a^2} \frac{dx}{\sqrt{x}(p^2 + x)}. \tag{18}$$

From (11) and (12) in connection with (17) we can obtain the coefficients of the continued fraction representing (15). The first five coefficients are:

$$\left.\begin{aligned} b_1 &= \frac{\pi a}{4R_L}, \qquad b_2 = \frac{3aR_L}{\pi}, \qquad b_3 = \frac{5\pi a}{16R_L} \\ b_4 &= \frac{28aR_L}{9\pi}, \qquad b_5 = \frac{81\pi a}{256R_L}. \end{aligned}\right\} \tag{19}$$

If we denote the network represented by the partial fraction terminating with b_n as the "nth partial network," the transient response of the first and fifth partial networks is given in Fig. 1. The convergence of the response toward the prescribed response is clearly shown.

The circuit diagram of the fifth partial network is given in Fig. 2. The first member is a shunt capacitance, with which is included the input capacitance of the electron tube.

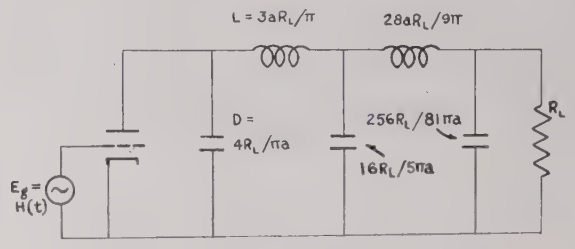


Fig. 2—Fifth partial network.

Since, at $p = 0, \phi$ must be equal to R_L, the partial networks must terminate with a resistance of value R_L. In each case, R_L represents the limit of the impedance of the infinite network following the partial network.

V. Conclusions

Mathematical techniques exist that are adequate for the synthesis of finite networks whose transient response approximates a prescribed response as well as desired. The main obstacle to bringing this method of network synthesis from the realm of theory to the realm of practice is the difficulty of finding a suitable form for $F_r(t)$. Many plausible functions will be found to have Laplace transforms which are not positive functions. On the other hand, two functions equally good as approximations to the desired response, and each with satisfactory transforms, may lead to network functions which converge at widely different rates.

Another problem of importance will be the means of combining transient and steady-state prescribed conditions. For instance, in the design of television intermediate-frequency amplifiers, the steady-state conditions to be included are the rejection of one sideband, and of the sound channel.

Acknowledgment

Acknowledgment is made to T. J. Higgins, professor of electrical engineering at the Illinois Institute of Technology, who first brought the Poisson-Stieltjes integral to the attention of the author.

Transient Response of Cathode Followers in Video Circuits*

B. Y. MILLS†

Summary—**The behavior of cathode followers handling the irregular video signals of radar or television is discussed. It is shown that the signal-handling ability of a cathode follower may be reduced if it has a capacitive load. A general expression for the magnitude of this reduction is given, and its effect on design procedures is discussed.**

I. Introduction

THE USE OF cathode followers for providing low-impedance outputs with a small current drain and low distortion is well known, but in general their behavior when operating into a capacitive load is the subject of some misconception. The object of the present paper is to show the limitations this behavior imposes on the design of cathode followers required for handling the irregular video signals of radar or television.

The exact shape of these signals depends on the nature of the circuits preceding the cathode follower. The signals may be represented approximately, however, as a series of positive and negative linear transitions of constant transition time T, as illustrated in Fig. 1. The transition time of the actual signals is conventionally

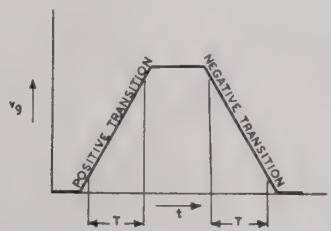


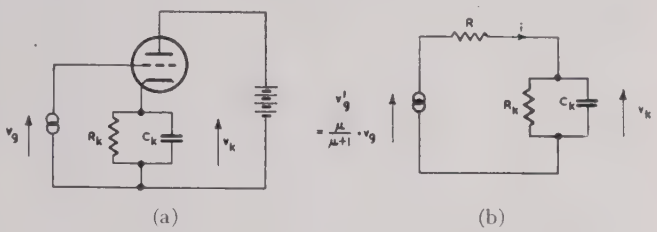
Fig. 1—A typical signal.

taken as the time required for the voltage to change from 10 to 90 per cent of its final value.[1] When applied to a linear transition, this value will be conservative, provided that there is little or no overswing in the original.

The requirement usually imposed on a cathode follower is that such transitions be reproduced with little distortion. It will be shown that the presence of capacitance in parallel with the cathode load resistor may then result in a reduction of the maximum signal amplitude which may be handled. Although this effect is qualitatively familiar to most circuit designers, no quantitative analysis immediately applicable to video signals has so far been published. It is common to see uneconomical designs based on an exaggerated respect for the limitation.

II. The Equivalent Circuit

In the analysis it has been found convenient to use the equivalent circuit of Fig. 2(b). The cathode follower of Fig. 2(a) can be represented there by putting its internal resistance R equal to $1/gm \cdot \mu/\mu+1$.



(a) (b)

Fig. 2—The cathode follower and equivalent circuit.

Nonlinearity of tube characteristics is neglected in the mathematical analysis, although its effect is demonstrated qualitatively in the final equations. As explained later, its presence does not greatly affect the usefulness of the results.

III. Resistive Cathode Load

Before commencing a discussion of transient behavior in the equivalent circuit, it is desirable to write down some of the relations needed which apply to the simple resistive-loaded case. These relations hold when the transition time of the applied signal is long compared with the time constant of the cathode load R_k C_k, so that the capacitance C_k may be ignored.

The gain of a cathode follower with cathode load R_k is given by the ratio of the cathode voltage v_k to the grid voltage v_g:

$$A = \frac{v_k}{v_g} = \frac{R_k}{R + R_k} \cdot \frac{\mu}{\mu + 1} . \tag{1}$$

A more useful concept turns out to be the gain of the equivalent circuit A', given by the ratio of the cathode voltage v_k to the input voltage of the equivalent circuit v_g'.

$$A' = \frac{v_k}{v_g'} = \frac{R_k}{R + R_k} . \tag{2}$$

It is also necessary to define the maximum output voltage swing V_0 as the maximum amount by which the output voltage can change in a given direction from any particular reference level. In a negative direction the limit is set by cathode current cutoff, or sometimes sim-

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† Council for Scientific and Industrial Research, Chippendale, N. S. W., Australia.

[1] Transition times for common circuits are given by a number of authors. See, in particular, H. E. Kallmann, R. E. Spencer, and C. P. Singer, "Transient response," Proc. I.R.E., vol. 33, pp. 169–196; March, 1945.

ply an increase in distortion. In a positive direction the usual limitation is the drawing of grid current. If I_0 is the corresponding cathode-current change,

$$V_0 = R_k I_0 \tag{3}$$

IV. Capacitive Cathode Load

Turning now to the case of an applied signal with a short transition time, we may divide the analysis into two parts. The first part deals only with the small-signal response. The second deals with the limitation on maximum output voltage caused by the short transition time of the applied signal.

As far as the small-signal response is concerned, it is sufficient to note that the transient response of a cathode follower is the same as that of a resistance-coupled pentode amplifier with plate load $A'R$ (consisting of R and R_k connected in parallel) shunted by a capacitance of C_k. The behavior of such a circuit to various signal forms is well known.[1] In particular its response to a linear transition is given by equation (9) of the Appendix. It is seen that, provided $\exp(-1.25T/A'RC_k)$ is small, the signal is reproduced with little distortion and delayed by a time $A'RC_k$.

A cathode follower which has an adequate small-signal transient response may, however, display severe transient distortion on a signal which would appear to have an amplitude well within the capabilities of the tube. The reason is that in reproducing accurately a linear transition, a cathode follower must supply a steady current of $dv_k/dt \cdot C_k$ to the capacitance C_k during the rise (or fall) time of the signal. The available current swing through the load resistance R_k is therefore reduced, and consequently the signal-handling capabilities of the tube may be severely restricted. The following relation between the maximum output-voltage swing possible with a signal transition time T and the maximum available voltage swing (i.e., for $T=\infty$) is derived in the Appendix:

$$V_T = \frac{V_0}{1 + A' \dfrac{R_k C_k}{1.25T}} \tag{4}$$

where V_T is the maximum output voltage swing with transition time of T, and V_0 is the maximum available output voltage swing.

It is assumed that $\exp(-1.25T/A'RC_k)$ is small or, in other words, that the transient distortion with a small input signal is not large. The equation applies to both positive and negative transitions.

In a cathode follower handling a positive signal and biased near anode-current cutoff, the limitation occurs usually on the negative-going trailing edge, and its effect is often apparent as a considerable lengthening of this portion of the signal. In such a case the distortion is the result of insufficient available voltage swing in a negative direction, which causes the cathode current to be cut off. The effective time constant of the cathode circuit is thereby changed from $A'RC_k$ to R_kC_k, with consequent distortion.

Equation (4) can be shown to apply also when C_k is replaced by an open-circuited transmission line with propagation time considerably shorter than T, and with a total capacitance of C_k. This is analogous to the similar and more familiar representation of an open-circuited transmission line carrying a sine-wave signal of a frequency considerably less than the lowest resonant frequency of the line.

V. Cathode Follower Design

For design purposes it is better to write (4) in a different form. In Fig. 3 are represented the cathode voltages in a cathode follower handling a typical positive signal. Consider the negative transition, as it is the one in which trouble is usually expreienced. It will be assumed that the signal amplitude is the maximum which can be handled without cathode-current cutoff.

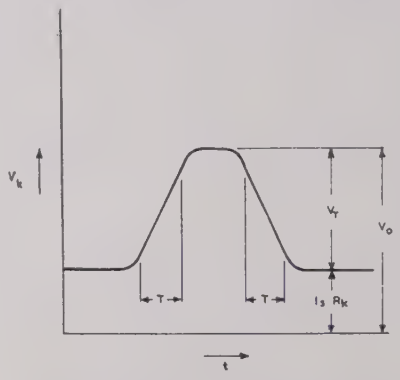

Fig. 3—Cathode voltages with a typical positive signal.

The cathode current necessary to maintain a steady voltage across R_k equal to the minimum cathode voltage is taken as I_s. The available voltage swing V_0 is then equal to $V_T + I_s R_k$, whence (4) takes the form

$$V_T = \frac{V_T + I_s R_k}{1 + A' \dfrac{R_k C_k}{1.25T}},$$

which, on rearranging, becomes

$$I_s = V_T \cdot \frac{A'C_k}{1.25T}. \tag{5}$$

In the design of a cathode follower in which the negative transition is the determining factor, it is therefore necessary to ensure that the minimum steady cathode current I_s is greater than that obtained from (5). This equation is based on the ideal linear circuit of Fig. 2(b). Actually, of course, the internal resistance of a cathode follower increases steadily as the anode current is decreased. This will result in a higher possible value of V_T

before cutoff occurs because of the decrease in A', but a lower value before transient distortion increases perceptibly. In practice, the equation as given will often represent a suitable compromise. If it is necessary to ensure that the internal resistance R should never exceed a certain value, then I_s must be increased by an amount equal to the cathode current corresponding to the maximum allowable internal resistance.

It will be observed that the signal-handling capacity apparently does not depend to any great extent on R_k, provided that the gain A' is near unity. This is because the negative transition only has been considered. In a cathode follower designed to have the minimum value of I_s, the peak cathode current will be given by

$$I_{(\max)} = \frac{V_T}{R_k} + 2I_s. \tag{6}$$

The current I_s is doubled because an extra current of this magnitude is required to reproduce the positive transition.

The peak current must, of course, be within the capabilities of the tube, and usually it is desirable that it should be as small as possible in order to keep the tube dissipation to a minimum.

Usually, therefore, the cathode resistor should be made as large as possible. In the most common practical circuit the signal is coupled to the cathode follower grid via a capacitor and grid-leak combination in which the cold end of the grid leak is at earth potential. The minimum grid voltage is then zero, or even negative, if the duty cycle of the signal is appreciable.

The maximum value of R_k is then limited to that which produces a cathode current I_s given by (5) when the grid has this minimum voltage. Often a more economical design is, therefore, one in which the cathode resistor is larger than this, and the grid leak is returned to a positive voltage sufficient to keep I_s above the minimum value.

VI. Acknowledgment

This work was carried out as part of the research program of the Division of Radiophysics, Council for Scientific and Industrial Research, Commonwealth of Australia.

APPENDIX

Maximum Voltage Output

A cathode follower with capacitive load may be represented by the simplified circuit of Fig. 4, on applying Thévénin's theorem to the euqivalent circuit of Fig. 2(b). The input signal to this circuit is then the output of the cathode follower in the absence of the capacitance C_k, while the voltage across the capacitance C_k is the actual cathode voltage v_k. The input signal to be considered is a linear transition of magnitude V_T and transition time T. It is required to find the relationship between this applied signal and the maximum change of cathode current I_0 at time $1.25T$.

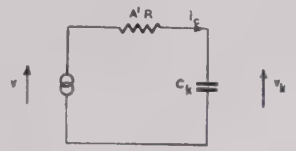

Fig. 4—Simplified equivalent circuit for calculation. of the instantaneous value of the cathode voltage V_k.

The slope of the applied signal is equal to $V_T/1.25T$; that is,

$$v = \frac{V_T}{1.25T}\, t. \tag{7}$$

It may be shown that, if a signal consisting of a linearly changing voltage with the above slope is applied to the circuit of Fig. 4, the magnitude of the current i_c flowing into the capacitor during the transition time of the signal is given by

$$i_c = \frac{V_T}{1.25T} \cdot C_k \left\{1 - \exp\left(\frac{-t}{A'RC_k}\right)\right\}. \tag{8}$$

The voltage v_k across the capacitor is then given by

$$v_k = v - A'Ri_c$$

$$= V_T\left[\frac{t}{1.25T} - \frac{A'RC_k}{1.25T}\left\{1 - \exp\left(\frac{-t}{A'RC_k}\right)\right\}\right]. \tag{9}$$

The total cathode current is the sum of current flowing into C_k and R_k. The former is given by (8) above; the latter is equal to v_k/R_k. Thus, on adding these and rearranging, we have, for the cathode current,

$$i = \frac{V_T}{R_k}\left[\frac{t}{1.25T} + \frac{A'R_kC_k}{1.25T}\left\{1 - \exp\left(\frac{-t}{A'RC_k}\right)\right\}\right] \tag{10}$$

The maximum value of i, equal to I_0, occurs at a time of $1.25T$. Inserting these values for i and t in (10) and rearranging, we have

$$V_T = \frac{I_0R_k}{1 + A'\dfrac{R_kC_k}{1.25T}\left\{1 - \exp\left(\dfrac{-1.25T}{A'RC_k}\right)\right\}}. \tag{11}$$

Since the requirement of small transient distortion dictates a small value for $\exp(-1.25T/A'RC_k)$, this equation may normally be simplified to

$$V_T = \frac{V_0}{1 + A'\dfrac{R_kC_k}{1.25T}}. \tag{4}$$

A Microwave Impedance Bridge*

M. CHODOROW†, SENIOR MEMBER, IRE, E. L. GINZTON†, SENIOR MEMBER, IRE, AND F. KANE†

Summary—A six-arm waveguide structure is described which is a true microwave equivalent of a Wheatstone bridge. A theoretical analysis of the equivalent circuit of the device has been made, using the symmetry properties of the structure. The resulting relation among the admittances of the various arms is exactly that of a Wheatstone bridge with shunting susceptances across each pair of terminals. A device of this sort for use at 10 cm has been built and tested, and was found to behave as predicted.

With this bridge it is possible to measure any impedance to about the same accuracy as with a standing-wave detector. A valuable feature of this instrument is that the standard impedances required are three variable reactances (movable shorting plungers) and a Z_0 termination. The data are obtained in the form of three lengths, the positions of the movable shorts.

Since the device is the complete equivalent of a Wheatstone bridge, it can also be used as a four-terminal lattice section in filter design or in any other related application requiring the microwave equivalent of a lattice section. This allows all the greater flexibility which lattice sections have, as compared to tee or pi sections commonly used in microwave work.

I. Introduction

ANY COMPARISON method of measuring impedances at microwave frequencies requires two things: (1) some sort of device which can function as a bridge, and (2) an impedance standard. There have been a number of microwave devices invented which measure impedances by comparison. Few of them, however, are actually bridges in the sense that one uses the term at low frequencies. A true bridge of the Wheatstone type obeys the equation

$$AB = CD$$

or

$$B = \frac{C}{A} D. \tag{1}$$

Here, A, B, C, and D are four impedances, three of of which are known and the other is unknown. By this criterion, for example, a magic-tee or hybrid junction is not a bridge, for it obeys the equation

$$A = B. \tag{2}$$

The difference between (1) and (2) is not academic. For (2) it is necessary to provide an adjustable impedance which will exactly equal the unknown. That is, the standard impedance will require both a variable resistance and a variable reactance. A variable resistance is difficult to provide at microwave frequencies, and this is a drawback to the use of a device based on (2). With a true bridge which obeys (1), however, it is possible to match any impedance by use of a fixed resistance only plus variable reactances, both of which, in practice, are quite simple to make at microwave frequencies. For example, let B be the unknown. Then, if A and C are variable reactances consisting of shorted sections of transmission line of variable length, the ratio C/A can be adjusted to have any real value desired. D consists of a perfectly terminated line in series with a variable reactance, which is another shorted-section line. By adjusting the latter, D can be made to have any arbitrary phase angle. Therefore D can be adjusted to have the phase angle of the unknown, and the ratio C/A can be adjusted to give the correct magnitude. The value of the unknown B, then, is determined from the three physical lengths of stubs A, C, and D.

A Wheatstone bridge satisfying (1) has six-terminal pairs, the four impedance arms, and an input and output arm, and therefore such a device at microwave frequencies requires connecting six waveguides or transmission lines in a suitable way so that the combination is a bridge. This is not topologically simple.

The device shown in Fig. 1 is such a combination, and is a true microwave equivalent of a Wheatstone bridge. It was first suggested by R. Dicke, formerly of the MIT Radiation Laboratory. It is made by joining six pieces of rectangular waveguide at a symmetrical junction. Each waveguide then represents an arm of the bridge, or the input, or the detector. Opposite pairs of arms, such as A and C or B and D, lie on common axes but are rotated 90° with respect to each other. A bridge of this sort has been constructed and tested. It is shown

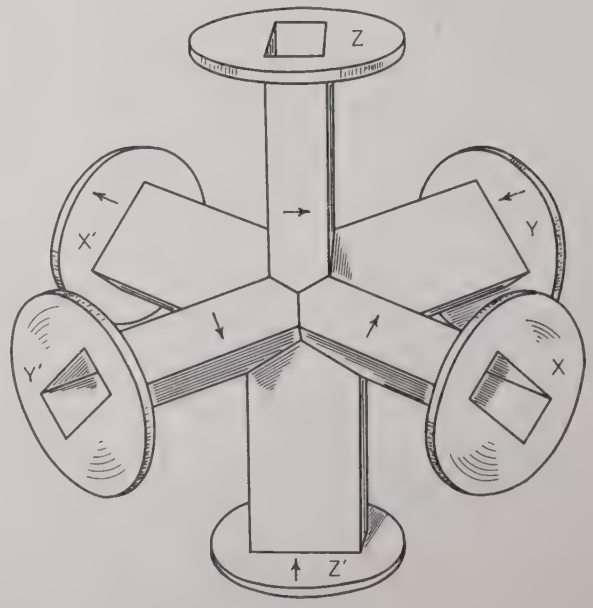

Fig. 1—A waveguide impedance bridge.

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in Fig. 2. It was made of $3\times1\frac{1}{2}$ inch waveguide, which is the standard size used in the 10-cm region.

Fig. 2—A photograph of an early waveguide bridge.

That the device shown in Fig. 1 is a Wheatstone bridge appears plausible from consideration of the geometry and the way in which the various guides are connected. Although this intuitive picture indicates that the device is a true bridge, it was thought useful to show analytically that this is indeed the equivalent circuit.

The procedure was to select sets of waves in the structure, such that the field distribution due to any arrangement of terminating admittances and sources can be represented by linear combination of these waves. Then, upon consideration of these waves and the symmetry properties of the bridge, relations between the input admittance at one terminal pair and all the other five terminating admittances can be found. The waves that are set up are for the lowest mode in the waveguide only; that is, it is assumed that one is measuring the field sufficiently far from the junction of the guides so that all the higher modes which are present in the fringing fields at the junction are attenuated. The effect of the junction appears in the equation for the bridge, in the form of equivalent lumped susceptances at suitably chosen reference planes in the guides. The expression for the admittance relation among the six arms is

$$\begin{aligned} &y_x y_{x'} y_z + y_x y_{x'} y_{z'} + y_x y_{z'} y_y + y_x y_{z'} y_{y'} + y_y y_{y'} y_z \\ &+ y_y y_{y'} y_{z'} + y_y y_{y'} y_x + y_y y_{y'} y_{x'} + y_z y_{z'} y_x \\ &+ y_z y_{x'} y_{z'} + y_z y_{z'} y_y + y_z y_{z'} y_{y'} + y_z y_y y_z \\ &+ y_{x'} y_{y'} y_z + y_z y_{y'} y_{z'} + y_{z'} y_y y_{z'} = 0, \end{aligned} \tag{3}$$

where

$$y_x = Y_x + jb \qquad y_{x'} = Y_{x'} + jb, \text{ etc.},$$

and Y_x is the terminating admittance on arm x, etc. This is the equation of a Wheatstone bridge with fringing susceptance of magnitude jb across each terminal. The derivation of (3) will be given in a subsequent section.

In terms of this general admittance relation, the condition for a balanced bridge is that the input admittance is independent of the detector admittance, and a relation of the form (1) will fulfill this requirement. This balance equation, as modified by the fringing susceptances and using a slightly different notation, can be written as

$$(Y_A + jb)(Y_B + jb) = (Y_C + jb)(Y_D + jb). \tag{4}$$

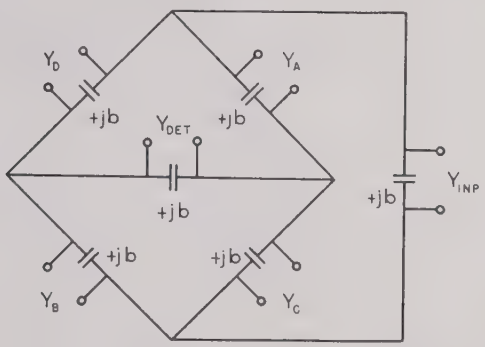

Fig. 3—The exact equivalent circuit of the waveguide bridge.

The equivalent circuit is shown in Fig. 3.

II. Construction and Experimental Investigation

The bridge to be described here was made of $3\times1\frac{1}{2}$ inch waveguide and was operated in the TE_{10} mode. Such a bridge can be made for rectangular waveguide of any dimensions. The ends of the waveguides which come together at the junction have triangular tongues cut in each side with angles as shown in Fig. 4. When the

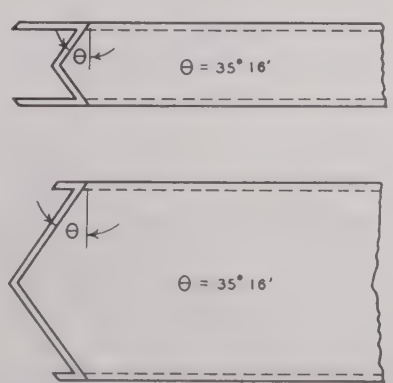

Fig. 4—One arm of the six-arm waveguide bridge.

six guides are placed together, these tongues mate to give the correct orientation for all the guides. The structure can then be clamped and soldered. Measurements

were made on the bridge to test the correctness of the equivalent circuit shown in Fig. 3.

As is always the case, for such equivalent circuits to be applicable, the admittances or impedances must be referred to certain special planes in the various arms of the structure. In this case, the equivalent plane for any of the bridge arms is the position of a shorting plunger which will cause a short to appear in the corresponding branch of the equivalent circuit. It is clear that, if the admittances Y_A, etc., which are measured at such equivalent planes satisfy an equation of the form (4), they will, in general, no longer satisfy it after they have been transformed an arbitrary distance down the line

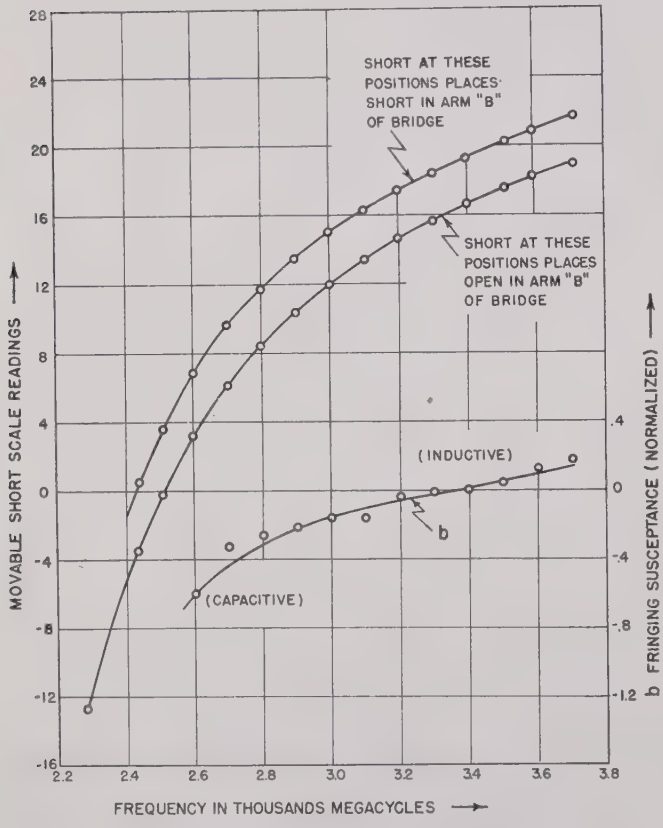

Fig. 5—Positions of critical planes versus frequency for one arm of six-arm bridge (without reactance tuning screw).

from the place at which they were originally defined. These equivalent planes can be located by moving shorts in two adjacent arms, such as A and C, until the standing-wave ratio in the input circuit is infinite. In this case, the positions of the shorts determine the equivalent planes in A and C. The position of the node in the standing wave in the input arm also defines the equivalent plane in that arm.

A more practical method for locating the equivalent plane was actually used. This method depends on the fact that when shorts are located at the equivalent planes of A and C, corresponding to infinite admittances in the branch A–C, then the output of the detector is zero, independent of variations in Y_B and Y_D. The admittances Y_B and Y_D were modulated by setting rotating electric fans near the open ends of arms B and D, resulting in a modulated detector output. The short positions in A and C were varied until the detector output was reduced to zero, which determined the equivalent planes for these arms, and also in the input arm. Planes in the other arms are located in the same way, by choosing different input arms.

There is another position of the shorts which gives zero detector output. This corresponds to the case when Y_A+jb and $Y_C+jb=0$. In this case, as seen from the input circuit, the bridge has a finite impedance and a finite standing wave ratio which distinguishes it from the former case when Y_A and Y_C were infinite. This second way of producing zero detector output permits the determination of the magnitude jb. Thus, if the position of the short, which makes the total admittance $Y_A+jb=0$, is a distance l from the equivalent plane, $Y_A=-jY_0\cot 2\pi l/\lambda g$ and $b=Y_0\cot 2\pi l/\lambda g$. The value of this fringing susceptance was found to be about 0.2 Z_0 at 10 cm. Due to asymmetries in construction, this varied slightly from arm to arm by about 10 per cent. It was also frequency-dependent. Fig. 5 shows the value of this fringing susceptance and also the relative position of the equivalent plane as a function of frequency. The value of the fringing susceptance becomes zero and changes sign at 3.4 kMc. This fringing susceptance can be eliminated at any particular frequency by inserting a capacitative screw at the position of the equivalent plane or a quarter wavelength away, depending on the sign of the jb. No attempt was made to provide a broad-band susceptance which would eliminate the fringing susceptance over a wide range of frequency. In use as a bridge, a calibrated moveable short was placed on arm D in such a position that normalized admittance $1+jY$ appeared at the equivalent plane. Moveable shorts were attached to arms A and C and the admittance to be measured was attached to arm B. If the fringing susceptance has been eliminated as described above, then Y_B is given by the equation

$$Y_B = \frac{Y_C}{Y_A} Y_D.$$

Since Y_C/Y_A is a dimensionless number M, $MY_D = M(1+jY)$ will cover the whole admittance plane. A Smith chart, Fig. 6, shows a comparison of some impedances measured first by the bridge described and then by a conventional standing-wave detector using a nodal-shift method.

Once properly adjusted, the bridge is simple to use, and measurements can be made rapidly. The unknown impedance is determined in terms of three physical lengths, the distances of the shorts from their correct reference planes, which is a very simple standard and is independent of detector calibration. The accuracy of the measurement is equivalent to that of a good standing-wave detector. The use of the three physical lengths

to specify the unknown impedance can be facilitated with the aid of simple formulas or charts. Although, in the current version of the bridge described here, the fringing susceptance was eliminated for only one frequency, it should be possible by conventional broadbanding techniques to make the device quite broadband, so that the fringing susceptance is almost zero over a considerable range of frequency.

III. Theory

To find the equivalent circuit for the structure shown in Fig. 1, it is necessary to set up suitable basis fields in the various arms such that any possible field can be represented as a linear combination of these. Then, by consideration of the symmetry properties of the structure, it is possible to get the relation between admittances in the various arms. This method is similar

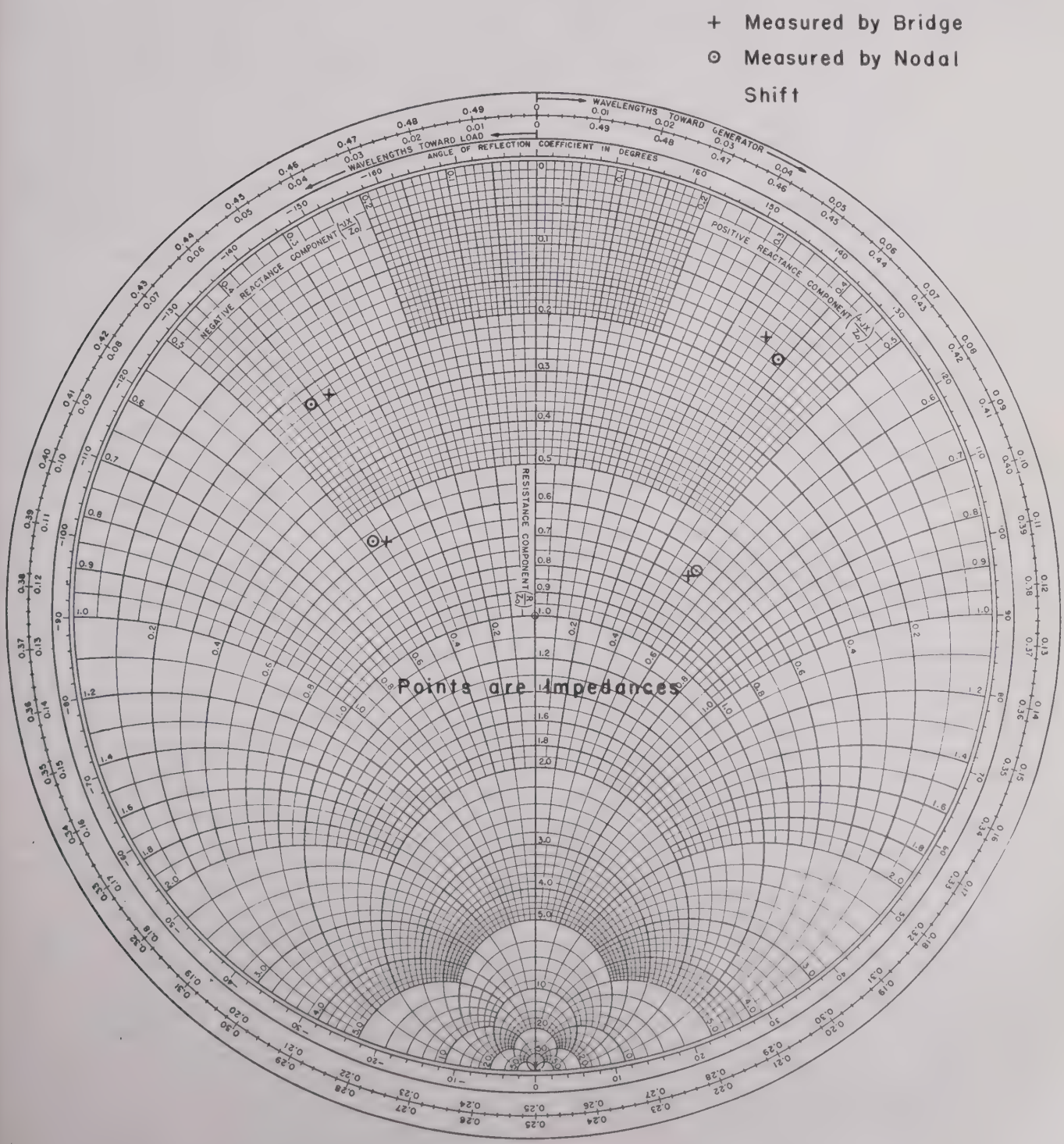

Fig. 6—Showing some bridge measurements compared to known impedances determined by nodal shift technique.

to that used by Slater[1] to obtain equivalent circuits for series and shunt tees and similar structures. In the cases treated by Slater it is possible to select the basic field distributions by inspection. The bridge discussed here has a more complicated symmetry, and the choice of a suitable set of basic fields is facilitated by use of the formal methods of group theory. The latter, however, are not indispensable.

The field in a waveguide can be represented in the following fashion (co-ordinates u, v, z):

$$E_u = \frac{2}{ab} \frac{\sin \pi v}{a} e^{j\omega t} V(z)$$

$$H_v = -\frac{2}{ab} \frac{\sin \pi v}{a} e^{j\omega t} I(z)$$

where $V(z)$ and $I(z)$ represent an equivalent voltage and current. It is possible to define an impedance

$$\frac{E_u}{-H_v} = \frac{V(z)}{I(z)}.$$

For a traveling wave in $\pm z$ direction,

$$\frac{V(z)}{I(z)} = \pm Z_0 = \pm 377 \frac{\lambda_g}{\lambda_0},$$

and

$$V = \pm IZ_0 = V_n e^{\pm(2\pi z/\lambda_g)j} = V_n e^{\pm \beta z j}$$

where V_n is the amplitude and $\beta = 2\pi/\lambda_g$. Instead of traveling waves, it will be convenient to use standing waves expressed in terms of I and V.

It is necessary to choose a reference plane for these standing waves and also a direction of the positive E vector in each arm. Choose axes x, x', y, y', z, z' along each arm as shown in Fig. 1, all having positive direction outward from the junction. The direction of the positive E vector in each is also shown in the diagram. The functions will be expressed in terms of sin βz and cos βz, etc., but these have no significance so far as evenness or oddness with respect to the junction is concerned. Since the E vector in z' waveguide and the z waveguide are oriented at right angles to each other, there is no such simple symmetry property through the junction for the E vector. Instead, the cosine and sine merely refer to the behavior of the function in its own particular waveguide, as referred to some arbitrary reference plane. These planes are assumed to be located at the same position in each guide. It turns out that the appropriate functions can be divided into two sets of three each. The three functions constituting each set are degenerate in the sense that one function describes a distribution in which there is a field in four of the guides, and the other two are obtained from it by permuting some of the indices. This will be somewhat clearer after we have written down the functions.

Listed below are the three functions comprising the first set:

I(1)	II(1)	III(1)
$A \sin \beta z$	$B \sin \beta z$	$C \sin \beta x$
$A \sin \beta z'$	$-B \sin \beta z'$	$C \sin \beta x'$
$-A \sin \beta x$	$B \sin \beta y$	$C \sin \beta y'$
$A \sin \beta x'$	$-B \sin \beta y'$	$C \sin \beta y$

It can be seen that these are independent, since it is not possible to get any one of them by linear combination of the other two.

The symmetry of this set can be illustrated by considering the function I(1). For the fields in the z and z' guides, the orientation is such that in the junction they can only have a resultant along the y or y' axis, and therefore cannot cause any fields in those wave-guides. The fields in the x and x' guides have the same properties. However, from the way we have chosen the signs and since the reference planes are at the same position in all of the guides, the resultant of the x, x' function will be in the opposite direction from that of the z, z' function. Another way of saying this is to consider the fields of I(1) as propagating unchanged from the waveguides into the junction region, i.e., as if the four waveguides concerned intersect each other without interfering with each other. In this case, at the midpoint, waves from all of these would cancel and give zero resultant.

For the next set there is a different type of symmetry. This set can be written as:

I(2)	II(2)	III(2)
$D \cos(\beta z - \phi)$	$E \cos(\beta z - \phi)$	$F \cos(\beta x - \phi)$
$D \cos(\beta z' - \phi)$	$-E \cos(\beta z' - \phi)$	$F \cos(\beta x' - \phi)$
$D \cos(\beta x - \phi)$	$-E \cos(\beta y - \phi)$	$-F \cos(\beta y - \phi)$
$D \cos(\beta x' - \phi)$	$E \cos(\beta y' - \phi)$	$-F \cos(\beta y' - \phi)$

The fact that this has been written as a cosine is of no significance as far as the evenness or oddness about the junction is concerned, and the phase angle in the cosine merely means that the zero amplitude for these functions is not necessarily 90° from the reference plane of the first set. In general, the zero plane for one set will be shifted some arbitrary amount with respect to that of the other set. This depends on the details of the discontinuity at the junction and cannot be determined by this type of theory. It will appear in the theory as a fringing susceptance which can be determined empirically, once a fixed reference plane is selected for each guide. The significant thing about this set can be found by examining the behavior of the vectors in each waveguide where they come together at the junction. It is found that they behave differently than the first set. For example, if we consider functions I(2), the resultant of the z, z' functions will again be a vector along the yy' axes. The xx' functions also have a resultant vector along the yy' axes, but in this case as opposed to the set (1) the two vectors due to zz' set and xx' set are in the

[1] J. C. Slater, "Theory of Symmetrical T's," Research Laboratory of Electronics, MIT, Technical Report No. 37.

same direction at the junction midpoint. If we again imagine as before that the waveguides extend right through the junction intersecting without interfering with each other, the resultant vector at the center of the junction would be the sum of all four, and would not cancel as it did in set (1). The fact that this set is of different symmetry than the previous set can be shown rigorously by means of group theory. The necessity for this symmetry as well as for the other can also be shown. The details of the proof are omitted. Briefly it may be stated that the structure described here has the symmetry of the tetrahedral group and the functions I and II transform under different irreducible representations of this group.

The requirement of the phase shift ϕ for these functions as opposed to the first set is not proved since there is no symmetry property which determines this. It is to be stressed, however, that even if by some accidental property ϕ should equal 90°, i.e., the functions of both sets (1) and (2) should be sine functions in each guide, the symmetry of these functions with respect to the whole structure is not the same. It would still be true that, with regard to the whole structure, it would not be possible to form one distribution by a linear combination of the other five.

In terms of these distributions, it is now possible to set down the general expression for the voltage and current in each arm.

$$\begin{aligned}
V_x &= -A\sin\beta x + C\sin\beta x + D\cos(\beta x-\phi) \\
&\quad + F\cos(\beta x-\phi) \\
jI_xZ_0 &= +A\cos\beta x - C\cos\beta x + D\sin(\beta x-\phi) \\
&\quad + F\sin(\beta x-\phi) \\
V_{x'} &= A\sin\beta x' + C\sin\beta x' - D\cos(\beta x'-\phi) \\
&\quad + F\cos(\beta x'-\phi) \\
jI_{x'}Z_0 &= A\cos\beta x' - C\cos\beta x' - D\sin(\beta x'-\phi) \\
&\quad + F\sin(\beta x'-\phi) \\
V_y &= B\sin\beta y + C\sin\beta y - E\cos(\beta y-\phi) \\
&\quad - F\cos(\beta y-\phi) \\
jI_yZ_0 &= -B\cos\beta y - C\cos\beta y - E\sin(\beta y-\phi) \\
&\quad - F\sin(\beta y-\phi) \\
V_{y'} &= -B\sin\beta y' + C\sin\beta y' + E\cos(\beta y'-\phi) \\
&\quad - F\cos(\beta y'-\phi) \\
jI_{y'}Z_0 &= B\cos\beta y' - C\cos\beta y' + E\sin(\beta y'-\phi) \\
&\quad - F\sin(\beta y'-\phi) \\
V_z &= A\sin\beta z + B\sin\beta z + D\cos(\beta z-\phi) \\
&\quad + E\cos(\beta z-\phi) \\
jI_zZ_0 &= -A\cos\beta z - B\cos\beta z + D\sin(\beta z-\phi) \\
&\quad + E\sin(\beta z-\phi) \\
V_{z'} &= A\sin\beta z' - B\sin\beta z' + D\cos(\beta z'-\phi) \\
&\quad - E\cos(\beta z'-\phi) \\
jI_{z'}Z_0 &= A\cos\beta z' + B\cos\beta z' + D\sin(\beta z-\phi) \\
&\quad - E\sin(\beta z'-\phi).
\end{aligned}$$

If one selects as the plane of reference in each guide the plane where $\sin\beta x$, $\sin\beta x'$, etc. $=0$, that is, where the voltages of set (1) are identically zero, this simplifies the above equations considerably. One can then write the admittances at these planes; these admittances being measured looking away from the junction. These admittances are:

$$\begin{aligned}
\frac{I_x}{V_x}jZ_0 &= \frac{A-C}{D+F}\frac{1}{\cos\phi} - \tan\phi \\
\frac{I_{x'}}{V_{x'}}jZ_0 &= \frac{A+C}{D-F}\frac{1}{\cos\phi} - \tan\phi \\
\frac{I_y}{V_y}jZ_0 &= +\frac{B+C}{E+F}\frac{1}{\cos\phi} - \tan\phi \\
\frac{I_{y'}}{V_{y'}}jZ_0 &= \frac{B-C}{E-F}\frac{1}{\cos\phi} - \tan\phi \\
\frac{I_z}{V_z}jZ_0 &= -\frac{A+B}{D+E}\frac{1}{\cos\phi} - \tan\phi \\
\frac{I_{z'}}{V_{z'}}jZ_0 &= \frac{B-A}{D-E}\frac{1}{\cos\phi} - \tan\phi.
\end{aligned}$$

Using the notation

$$y_x = \frac{I_x}{V_x} - j\frac{\tan\phi}{Z_0}, \text{ etc., or } y_x = V_x + jb$$

and eliminating the coefficients A, B, C, D, E, and F, one obtains (3).

IV. Four-Terminal Application

It should be pointed out that since this structure is the exact equivalent of a bridge, it can be used as a four-terminal lattice section in microwave filter design or in similar applications. Most microwave filter structures used to date have been the equivalents of ladder sections. As is well known, a lattice section is the most general form of four-terminal network, and offers much greater flexibility in design.[2]

For example, the image impedances and transfer constant can be separately adjusted. Also, any physical four-terminal network can be synthesized by means of lattice sections, while this is not always true for ladder sections.

[2] E. A. Guillemin, "Communication Networks," Vol. II, p. 378 ff., John Wiley and Sons, New York, N. Y.

Closed- and Open-Ridge Waveguide*

T. G. MIHRAN†, STUDENT MEMBER, IRE

Summary—**Expressions are developed for the voltage-current and voltage-power impedance of closed-ridge and open-ridge waveguide, with the discontinuity capacitance taken into account. Approximate expressions for impedance are derived which are valid under given typical conditions.**

I. Closed-Ridge Waveguide

In a recent paper, Cohn presented much information on the cutoff frequency and impedance of closed-ridge waveguide.[1] He noted excellent experimental checks of theoretical calculations for cutoff frequency; also for impedance, providing the ratio of guide height to width was small. However, when this ratio was 0.5, calculated impedances were approximately 25 per cent too high. He stated, correctly, that the reason for this discrepancy was the partial neglect of the discontinuity capacitance at the edges of the ridge in the derivation of the impedance equation. In the following calculation, the effect of this susceptance will be taken into account, giving expressions which are only slightly more complex than those derived by Cohn. In fact, Cohn's curves may be used to obtain a preliminary answer, which is then modified to include the total effect of the discontinuity.

Cohn's derivation of impedance was based upon the simplifying assumption that E lines within the guide run vertically from top to bottom. At the edges of the ridge, voltage was made continuous by assuming a discontinuity in E at that point. Impedance was defined as the ratio of voltage across the center of the guide to total longitudinal current on the top face. This current was calculated on the basis of the assumed distribution of E, thus neglecting the effect of the higher order modes

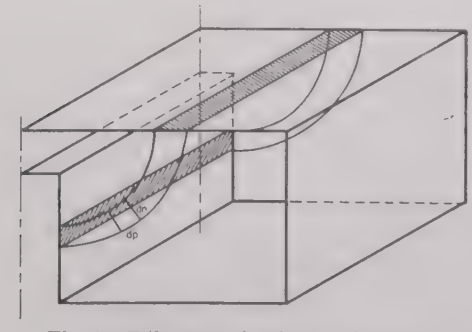

Fig. 1—E lines terminating on ridge side.

which are necessary to satisfy the boundary conditions at the edges of the ridge. As a result, when the ridge step was of appreciable size, the omission of the contribution of current due to the capacitance of the ridge edges resulted in a theoretical impedance which was too high.

This discontinuity current is readily evaluated. Consider two banks of E lines terminating on the side of the ridge in a ridge waveguide, as in Fig. 1. If their spacing is dn, the capacitance per unit length of the shaded conductors contained between the terminations of the E lines may be written as

$$dC = \frac{\epsilon_0 dQ}{\int Edp} = \frac{\epsilon_0 Edn}{V}.$$

The longitudinal current in either conductor is given by the tangential component of transverse H, i.e.,

$$dI_z = H_n dn = \frac{1}{Z_{TE}} Edn$$

where Z_{TE} is the ratio of transverse E to transverse H for a TE mode,

$$\frac{E_t}{H_t} = Z_{TE} = \frac{120\pi}{\sqrt{1 - \left(\frac{\lambda}{\lambda_c}\right)^2}}.$$

Hence,

$$dI_z = \frac{1}{\epsilon_0 Z_{TE}} VdC. \qquad (1)$$

Equation (1) states that current flow down the guide may be obtained by considering the product of voltage and capacitance. It is necessary to apply this equation only at the discontinuity, since the current in the rest of the guide walls has been determined by Cohn. In ridge guide there are two discontinuity capacitances at the edges of the ridge. Their presence, therefore, increases the total longitudinal current by the amount $2VC_d/\epsilon_0 Z_{TE}$, where C_d is the familiar Whinnery and Jamieson discontinuity capacitance[2] given in Fig. 2 of this paper. Strictly speaking, this value of C_d must be modified if the ridge edges are not far enough from the sides of the guide that reflection of higher-order modes is appreciable. However, with Cohn, these proximity effects are neglected in the determination of C_d.

The derivation of an expression for impedance may now be carried through in a manner similar to that of Cohn, except that his expression for total longitudinal

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[1] S. B. Cohn, "Properties of ridge waveguide," Proc. I.R.E., vol. 35, pp. 783–788; August, 1947.

[2] J. R. Whinnery and H. W. Jamieson, "Equivalent circuits for discontinuities in transmission lines," Proc. I.R.E., vol. 32, pp. 98–114; February, 1944.

current must be augmented by the discontinuity current, namely, $2C_dE_0b_2 \cos \theta_2/\epsilon_0 Z_{TE}$. Since his impedance has been based on the ratio of voltage to current,

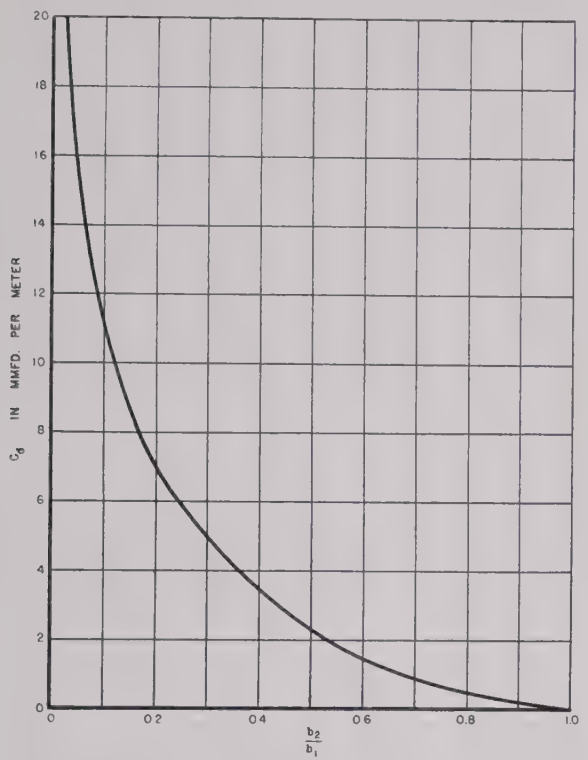

Fig. 2—Discontinuity capacitance as a function of ridge step.

it will be termed Z_{vi}. Accordingly, his equation (3) becomes

$$Z_{vi}^{\infty} = \frac{120\pi}{\dfrac{2C_d \cos \theta_2}{\epsilon_0} + \dfrac{\lambda_c'}{\pi b_2}\left[\sin \theta_2 + \dfrac{b_2}{b_1} \cos \theta_2 \tan \dfrac{\theta_1}{2}\right]}, \quad (2)$$

where

$$Z_{vi}^{\infty} = Z_{vi} \sqrt{1 - \left(\frac{\lambda}{\lambda_c'}\right)^2}$$

$$\theta_1 = \left(1 - \frac{a_2}{a_1}\right)\frac{\lambda_c}{\lambda_c'}\frac{\pi}{2}$$

$$\theta_2 = \frac{a_2}{a_1}\frac{\lambda_c}{\lambda_c'}\frac{\pi}{2}$$

λ_c = cutoff wavelength without ridge = $2a_1$

λ_c' = cutoff wavelength with ridge.

Equation (2) gives the impedance of single-closed-ridge guide as illustrated in Fig. 3(a). The impedance of the double-ridge structure is just twice that of the corresponding single-ridge guide.

If a narrow ridge is employed, $\theta_2 \ll 1$; $\cos \theta_2$ may be replaced by unity and $\sin \theta_2$ by θ_2, giving the approximate expression

$$Z_{vi}^{\infty} = \frac{120\pi}{\dfrac{2C_d}{\epsilon_0} + \dfrac{a_2}{b_2} + \dfrac{1}{\pi}\dfrac{\lambda_c'}{b_1}\tan \dfrac{\theta_1}{2}}. \quad (3)$$

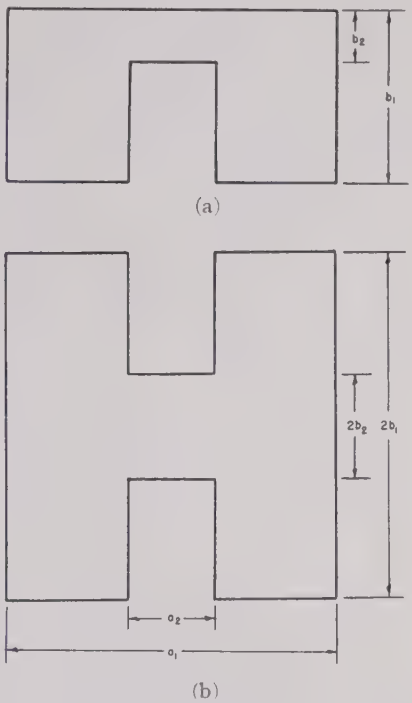

Fig. 3—Closed-ridge waveguide.

If $\lambda_c'/\lambda_c > 3$, little error results in replacing $\tan \theta_1/2$ by $\theta_1/2$, giving a very useful approximation which is independent of cutoff frequency

$$Z_{vi}^{\infty} = \frac{120\pi}{\dfrac{2C_d}{\epsilon_0} + \dfrac{a_2}{b_2} + \dfrac{1}{2}\dfrac{a_1}{b_1}\left(1 - \dfrac{a_2}{a_1}\right)}. \quad (4)$$

While the voltage-current definition of impedance is useful in problems dealing with the matching of guides, it should be remembered that the definition of impedance is not unique when circuit dimensions are an appreciable fraction of a wavelength. If it is desired to find the voltage developed across a guide for a given power propagating down it, a power-voltage impedance must be defined and calculated. Let this impedance be termed Z_{pv}. Then

$$Z_{pv} = \frac{V_0^2}{\displaystyle\int_{c.s.} E \times H da}. \quad (5)$$

The effect of the discontinuity capacitance may again be taken into account, with the aid of Fig. 2, by noting that

$$d^2P = E \times H da = \frac{1}{Z_{TE}} E^2 dn dp = \frac{1}{Z_{TE}} (Edn)(Edp).$$

Since $E\,dn$ is constant between the two E lines, the integration over p may be carried out, giving

$$dP = \frac{V}{Z_{TE}} E dn$$

From which

$$dP = \frac{1}{\epsilon_0 Z_{TE}} V^2 dC.$$

Hence, the additional power flow due to $2C_d$ is $2V^2C_d/\epsilon_0 Z_{TE}$. Writing (5) as

$$Z_{pv} = \frac{V_0^2}{\dfrac{2V^2C_d}{\epsilon_0 Z_{TE}} + \dfrac{1}{Z_{TE}} \displaystyle\int_{c.s.} E^2 da}$$

Cohn's expression for E may be inserted and the integration carried out, giving

$$Z_{pv}^{\infty} = \frac{120\pi^2 b_2}{2\pi b_2 \dfrac{C_d}{\epsilon_0} \cos^2\theta_2 + \lambda_c' \left\{ \dfrac{\theta_2}{2} + \dfrac{\sin 2\theta_2}{4} + \dfrac{b_2}{b_1} \dfrac{\cos^2\theta_2}{\sin^2\theta_1} \left[\dfrac{\theta_1}{2} - \dfrac{\sin 2\theta_1}{4} \right] \right\}}.$$

This simplifies, if a narrow ridge is assumed, to

$$Z_{pv}^{\infty} = \frac{120\pi}{\dfrac{2C_d}{\epsilon_0} + \dfrac{a_2}{b_2} + \dfrac{1}{\pi} \dfrac{\lambda_c'}{b_1} \dfrac{1}{\sin^2\theta_1} \left[\dfrac{\theta_1}{2} - \dfrac{\sin 2\theta_1}{4} \right]} \quad (6)$$

If $\theta_1 < 30°$, an excellent approximation is

$$Z_{pv}^{\infty} = \frac{120\pi}{\dfrac{2C_d}{\epsilon_0} + \dfrac{a_2}{b_2} + \dfrac{1}{3} \left(\dfrac{a_1 - a_2}{b_1} \right)}.$$

II. Open-Ridge Waveguide

The preceding expressions were developed primarily for determining the behavior of the open-ridge waveguide of Fig. 4, an advantageous structure for certain applications. In this guide, the discontinuity susceptance is a major factor governing guide impedance, since the shunt-capacitance has been greatly reduced by removal of the ridge top. So far, the equations have been corrected for the effect of C_d. They must be modified further to include the change of geometry and the resulting loss of capacitance. Henceforth, it will be assumed that the ridge is narrow and represents a lumped capacitance subject to a voltage V_0. The discontinutiy capacitance is also lumped with the ridge-top capacitance. A major problem is to determine how much the ridge-top capacitance changes when the bridging conductor is eliminated. The simplest approach to this problem is the experimental approach. Measurements have been made to determine the difference in capacitance between a ridge with and without a top. It was found that this change of capacitance ΔC depends chiefly upon the ratio of the inside spacing of the fins s to the ridge spacing b_2, providing this ratio is greater than unity. Experimental results for several fin thicknesses are presented in Fig. 5, from which it is evident that varying this parameter has little effect on ΔC. This handily eliminates an unwanted variable.

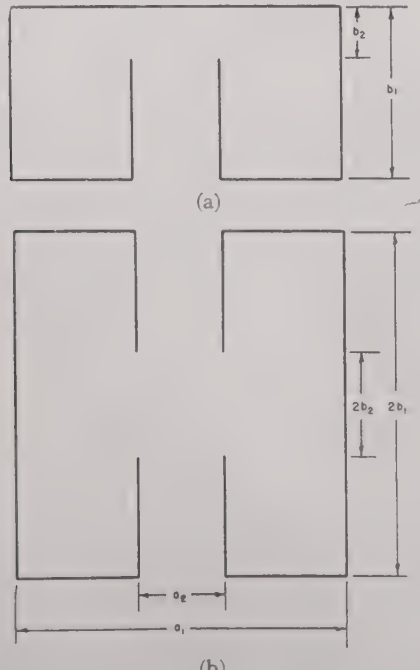

Fig. 4—Open-ridge waveguide.

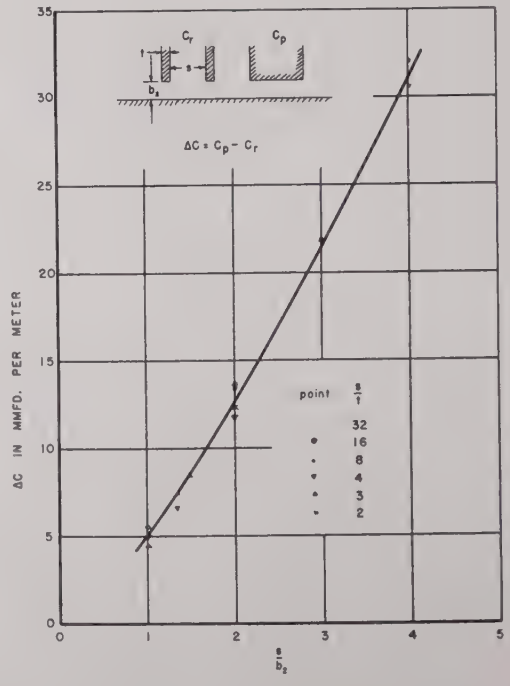

Fig. 5—Experimental determination of ΔC as a function of s/b_2.

Sufficient information is now available to calculate the cutoff wavelength and impedance of open-ridge waveguide. The expressions will again be developed for single-ridge guide, but apply equally well to double-ridge guide, providing the impedance is doubled. The

shunt admittance of $C_d+\frac{1}{2}C_r$ must equal the admittance of a transmission line of length θ_1 at cutoff, hence

$$\omega(C_d + \tfrac{1}{2}C_r) = Y_{01} \cot \theta_1.$$

Noting that $Y_{01}=1/120\pi b_1$, this may be written

$$\frac{\dfrac{b_1}{a_1}\left(\dfrac{2C_d + C_r}{\epsilon_0}\right)}{1 - \dfrac{a_2}{a_1}} = \frac{\cot \theta_1}{\theta_1}. \tag{7}$$

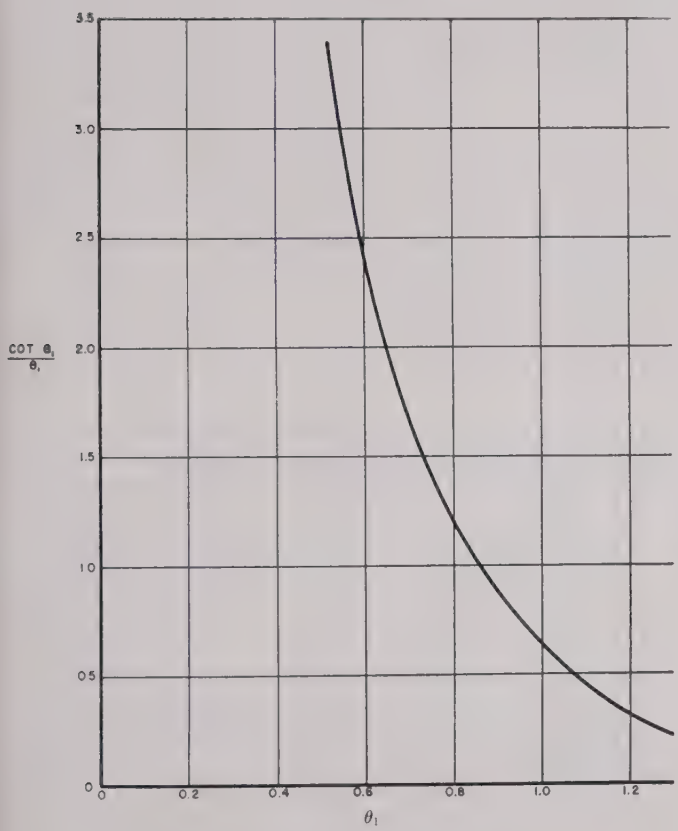

Fig. 6—Graphical solution of equation (7).

The solution of this equation may be found from the plot of Fig. 6, and λ_c'/λ_c obtained from the definition of θ_1,

$$\frac{\lambda_c'}{\lambda_c} = \left(1 - \frac{a_2}{a_1}\right)\frac{\pi}{2}\,\frac{1}{\theta_1}. \tag{8}$$

Impedance may now be obtained from (3) or (6), except that a_2/b_2 must be replaced by C_r/ϵ_0 as determined by

$$\frac{C_r}{\epsilon_0} = \frac{a_2}{b_2} - \frac{\Delta C}{\epsilon_0}. \tag{9}$$

Hence, for open-ridge guide,

$$Z_{vi}^{\infty} = \frac{120\pi}{\dfrac{2C_d + C_r}{\epsilon_0} + \dfrac{2}{\pi}\,\dfrac{\lambda_c'}{\lambda_c}\,\dfrac{a_1}{b_1}\tan\dfrac{\theta_1}{2}} \tag{10}$$

and

$$Z_{pv}^{\infty} = \frac{120\pi}{\dfrac{2C_d+C_r}{\epsilon_0} + \dfrac{2}{\pi}\,\dfrac{\lambda_c'}{\lambda_c}\,\dfrac{a_1}{b_1}\,\dfrac{1}{\sin^2\theta_1}\left[\dfrac{\theta_1}{2} - \dfrac{\sin 2\theta_1}{4}\right]}. \tag{11}$$

III. Sample Calculations

Consider a closed-ridge guide with $b_1/a_1=0.5$, $b_2/b_1=0.133$, and $a_2/a_1=0.352$. Cohn's Fig. 3 gives λ_c'/λ_c as 2.57 and a Z_{vi}^{∞} of 65 ohms. From Fig. 2 of this paper, C_d is found to 9.5 $\mu\mu$f/meter for a step of 0.133. Since ϵ_0 is 8.85 $\mu\mu$f/meter in mks units, the correction term may be evaluated, $2C_d \cos\theta_2/\epsilon_0=2.1$. Cohn's denominator must have been $377/65=5.8$, but this must be increased by 2.1. Hence, the impedance is $377/(5.8+2.1)=47.5$. Cohn reported experimental data on a similar guide, but with b_1/a_1 scaled down by a factor 0.472/0.500; its impedance was measured as approximately 50 ohms. Scaling 47.5 down by this factor, the corrected theoretical impedance is 45 ohms, a figure within 10 per cent of the experimental value. The approximate formula (4) gives 47 ohms.

Cohn gave a second example, a guide with $b_1/a_1=0.5$, $a_2/a_1=0.4$, and $b_2/b_1=0.1$. At a frequency one and one-half times cutoff, the uncorrected calculation gives 60 ohms, while including the discontinuity term reduces this to 46 ohms. Cohn reported 35 to 40 ohms experimentally. The approximate formula gives 45 ohms. Unfortunately, no further experimental data are available, but it is evident that the correction is in the right direction and of the right order of magnitude.

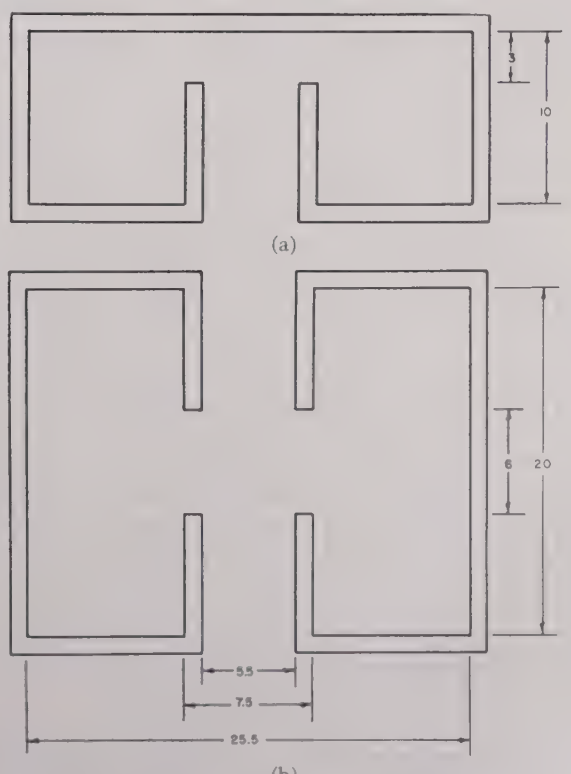

Fig. 7—Open-ridge guide for sample calculation.

As an example of open-ridge calculations, consider the guide of Fig. 7(a). Here $b_1/a_1=0.392$, $b_2/b_1=0.30$, and $a_2/a_1=0.294$. The discontinuity capacity for a step of 0.30 is given by Fig. 2 as 5.0 $\mu\mu$f/meter. The ΔC for a ridge with $s/b_2=5.5/3=1.83$ is given by Fig. 5 as 11 $\mu\mu$f/meter. Thus, from (9), $C_r=11$ $\mu\mu$f/meter. Substitution in (7) and use of Fig. 6 gives a θ_1 of 0.77. This allows evaluation of λ_c'/λ_c from (8), giving the value 1.44. Impedance is calculated directly from (10) and (11), giving $Z_{vi}^{\infty}=113$ ohms, and $Z_{pv}^{\infty}=124$ ohms.

No direct experimental check of these figures has been made; however, the above guide was set up in an equivalent form on a rectangular network analyzer designed and built at Stanford University under the direction of Spangenberg.[3] Measurement of λ_c'/λ_c from the board gave the value 1.65. This is within 15 per cent of the theoretical value, the lack of agreement probably being due to the difficulty of representing thin reentrant fins on the board, since it makes use of discrete lumped elements.

ACKNOWLEDGMENT

The writer wishes to thank E. L. Ginzton and M. Chodorow for their encouragement and guidance.

[3] K. Spangenberg and G. Walters, "An electrical network for the study of electromagnetic fields," Technical Report No. 1, ONR Contract N6-ori-106, Task III; May 15, 1947. This report describes a board designed for use with fields having cylindrical symmetry. Recently, however, another board has been constructed, one which allows solution of the two-dimensional wave equation in rectangular co-ordinates.

Broad-Band Dissipative Matching Structures for Microwaves*

HERBERT J. CARLIN†, MEMBER, IRE

Summary—**Interpolation in the complex plane is employed to handle microwave network functions. This yields an approximating rational function over a specified bandwidth, and leads to a lumped-circuit approximation for the microwave structure, which is used as a basis for the synthesis of matching networks. In various problems involving dissipative devices, the poles of the rational approximating function may satisfy special conditions. In such cases the ideal lumped matching network has a simple realizable form, and may be transformed into a suitable microwave structure. Applications of this method and experimental results are given for the synthesis of a new type broad-band coaxial "chimney" attenuator.**

I. INTRODUCTION

IN ORDER TO insure uniformity of apparatus design in a composite transmission system, and, at the same time, maintain conditions for maximum power transfer, it has been the practice to match the terminal impedance of components to the characteristic impedance of the main transmission line. This paper considers methods of design of microwave structures which match the input impedance of transmission components over very wide frequency bands. The matching structures are analogous to the constant-resistance networks of low-frequency circuit theory, and hence have loss. Thus the methods are most directly applicable to devices in which dissipation can be tolerated, such as attenuators, terminating loads, certain types of broad-band probes, etc. Later in the paper, applications of the method to the design of fixed pad coaxial "chimney" attenuators will be given.

The design procedure consists of essentially three steps:

Step 1: Determine the input driving point impedance function of the microwave device when properly terminated, and approximate this over a specified frequency band by a suitable rational function and its equivalent lumped-parameter circuit representation.

Step 2: Determine an ideal lumped-parameter matching network which, in combination with the lumped-circuit approximation of Step 1, produces a constant-resistance input impedance.

Step 3: Transform the ideal matching network of Step 2 into the final microwave matching structure.

II. REPRESENTATION OF MICROWAVE IMPEDANCE FUNCTIONS

The method employed here for approximating by a rational function the nonrational function which represents the input impedance of a specified microwave device, is that of interpolation in the complex plane. Algebraic methods of interpolation for the approximation of impedance functions have been used heretofore by Zobel,[1] but a more general method employing contour integration, described by Walsh,[2] appears to be little known to engineers. The basic theorem for interpolation in the complex plane may be stated as follows:

Let the function $f(s)$ be analytic in a region of the

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† Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

[1] Otto J. Zobel, U.S. Patent No. 1,720,777.

[2] J. L. Walsh, "Interpolation and Approximation by Rational Functions in the Complex Plane," Amer. Math. Soc. Colloq. Public Vol. XX, 1935, chap. VIII.

complex plane bounded by the contour Γ. Let the points $\beta_1, \beta_2, \cdots \beta_{n+1}$ lie inside Γ. Let $r(s)$ be a rational function of degree n with preassigned poles $\alpha_1, \alpha_2, \cdots, \alpha_n$ and of the form:

$$r(s) = \frac{b_0 s^n + b_1 s^{n-1} + \cdots + b_n}{(s-\alpha_1)(s-\alpha_2)\cdots(s-\alpha_n)}. \tag{1}$$

If $r(s)$ takes on the values of $f(s)$, i.e., interpolates to $f(s)$, at the points $\beta_1, \beta_2, \cdots, \beta_{n+1}$, then $r(s)$ is given by

$$r(s) = \frac{1}{2\pi j}\oint_\Gamma \left[1 - \frac{(s-\beta_1)(s-\beta_2)\cdots(s-\beta_{n+1})(t-\alpha_1)(t-\alpha_2)\cdots(t-\alpha_n)}{(t-\beta_1)(t-\beta_2)\cdots(t-\beta_{n+1})(s-\alpha_1)(s-\alpha_2)\cdots(s-\alpha_n)}\right]\frac{f(t)}{t-s}\,dt. \tag{2}$$

Equation (2) may be applied in a variety of ways, and can yield much information on the general nature of the interpolation process. For example, suppose all the β_k to be equal, i.e., a multiple point of interpolation. Then the integrand has a pole of order $n+1$ at β_k, and its evaluation by residues will involve the first n derivatives of $f(s)$ at $s=\beta_k$. If, now, the α_k are chosen $\alpha_k = \infty$, (2) will then reduce to

$$r(s) = a_0 + a_1(s-\beta_k) + a_2(s-\beta_k)^2 + \cdots + a_m(s-\beta_k)^n \tag{3}$$

where a_k become the coefficients of a Taylor series; $r(s)$ is thus given by the first n terms of a series expansion of $f(s)$ about the point $s=\beta_k$. This result indicates that the often-used practice of obtaining an approximation for a given function by using several terms of a power series expansion for that function is actually a form of interpolation in which all the interpolating points are identical.

In many cases the use of nonidentical points of interpolation distributed over the region in which an approximation is required gives better results than approximation by power series (i.e., repeated interpolation at a single point). A case in point is the approximation of nonrational impedance functions by lumped-parameter networks. For this, (2) may be applied if certain additional restrictions imposed by network realizability are added. A necessary condition that $r(s)$ be a network function is that the roots and poles of (1) be real or complex conjugate. It can be shown that, if this is to be true, then $r(s)$ may be determined by (2) in conjunction with the additional equations formed by setting the imaginary parts of the numerator coefficients b_k respectively equal to zero.

It should be pointed out that although $r(s)$ will satisfy certain necessary conditions for realizability as a driving-point impedance, it may still not be realizable. However, $f(s)$ is itself an impedance function, though of a distributed-parameter structure, and is in many ways similar to rational network functions.[3] Therefore, in practical problems $r(s)$ will usually turn out to be positive real and hence realizable; and even when this is not the case, additional devices may be employed, such as a slight change in the choice of interpolating points, to produce a realizable rational function.

As a simple illustrative example, and one which will be useful in a design problem to be considered later in this paper, consider the case of two interpolating points, $\beta_1 = 0$, $\beta_2 = jX_2$ where X_2 is a real linear function of either wavelength or frequency. Then $r(s)$ from (2) is

$$r(s) = \frac{-\alpha(s-\beta_2)f_1 - s(\beta_2-\alpha)f_2}{\beta_2(s-\alpha)}$$

where

$$f_1 = f_{1r} + jf_{1i} = f(\beta_1)$$
$$f_2 = f_{2r} + jf_{2i} = f(\beta_2).$$

If the imaginary part of the numerator coefficient in s is set equal to zero then α is found:

$$\alpha = \frac{X_2 f_{2i}}{f_1 - f_{2r}} \tag{4}$$

and

$$r(s) = \frac{s(f_{2r} - \alpha f_{2i}/X_2) - \alpha f_1}{s-\alpha}. \tag{5}$$

With appropriate values given for the parameters, (5) may be realized as a suitable network.

As an example of the application of (5), consider the input impedance to a long, lossy coaxial transmission line, which may be written:

$$f(s) = Z_0\sqrt{1-s}, \tag{6}$$

where

Z_0 = lossless characteristic impedance of the line
s = complex wavelength variable with imaginary part $= X = R\lambda/2\pi Z_0$
R = resistance per unit length of line
λ = real wavelength.

A range of $0 \leqq X \leqq 2$ is applicable to the class of lossy coaxial lines encountered in resistive-film microwave attenuators,[4] and may be chosen as the range of approximation for this example. The two points of interpolation may be determined by a method of least squares described in detail elsewhere,[5] or by inspection. The latter method generally yields satisfactory results and has the considerable advantage of saving much computational time when applicable. Suppose, then, that $X_1 = 0$, $X_2 = 1.6$. Substituting in (4) and (5), the result-

[3] H. W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Co., chap. 13, p. 298; New York, N. Y., 1945.

[4] H. J. Carlin and J. W. E. Griemsmann, "A bead supported coaxial attenuator," *1947 Proc. Nat. Electr. Conf.*, pp. 79–89.

[5] H. J. Carlin, Report R-139-47, PIB-90, Microwave Research Institute of the Polytechnic Institute of Brooklyn, p. 30; March, 1947.

ing function on the imaginary s axis is given by

$$r(X) = \frac{5.34 - j3.42X}{5.34 - jX}. \tag{7}$$

The real and imaginary parts of this approximating function are compared with the exact results obtained from (6) in Fig. 1. Shown also in Fig. 1 is the lumped-circuit representation of (7).

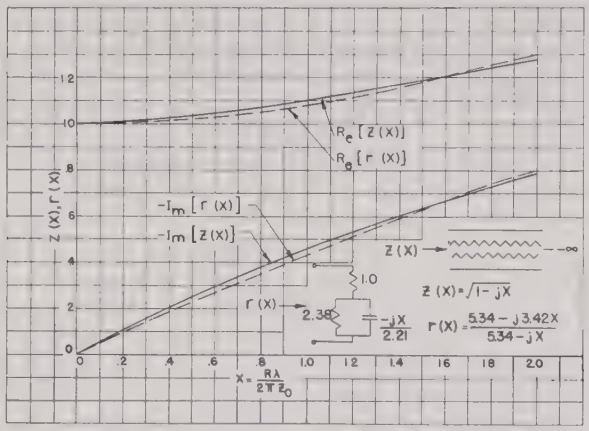


Fig. 1—Interpolation to the input impedance of dissipative coaxial line of infinite length.

Another example is plotted in Fig. 2. In this case the given distributed-parameter structure is a dissipative short-circuited coaxial line of length l, and resistance

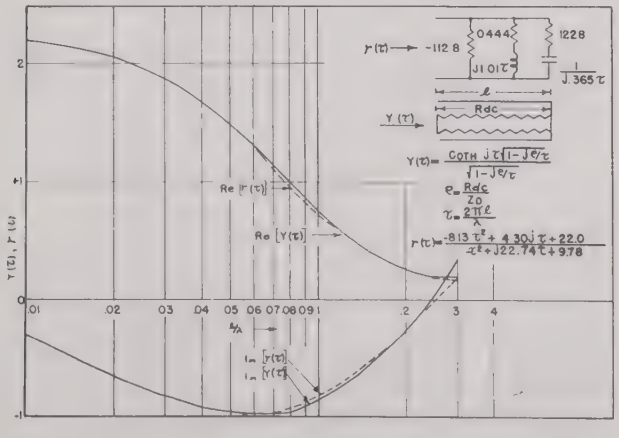


Fig. 2—Interpolation to the input impedance of a short-circuited dissipative coaxial line.

R_{dc}. Three points of interpolation were chosen at $l/\lambda = 0.0$, 0.05, and 0.20, respectively, to cover the range $0 \leqq l/\lambda \leqq 0.25$.

The input admittance function of the line is given by

$$Y(s) = \frac{Y_0 \coth \sqrt{1 + \rho/s}}{\sqrt{1 + \rho/s}} \tag{8}$$

and the interpolating rational function found from (2) is then

$$r(s) = \frac{8.13s^2 + 4.30s + 22.0}{s^2 + 22.74s + 9.78}, \tag{9}$$

where

s = complex frequency variable $= \sigma + j\tau$

$\tau = 2\pi l/\lambda$

$\rho = R_{dc}/Z_0$.

The real and imaginary parts of $r(j\tau)$ are plotted on Fig. 2, which also shows a lumped-circuit representation of (9). The network shown contains a negative resistance, although it can be rigorously shown that (9) is a positive real function in s, and hence realizable by a finite assemblage of positive resistors and reactors. This type of structure with negative resistance is chosen since it leads to a simple form of ideal matching network. This is discussed further in the next section.

III. Determination of Ideal Matching Networks

Having found a realizable lumped-circuit approximation for the given microwave structure, the next step in the design process is to find a lumped ideal matching network. Fano[6] has shown how to obtain a lossless network which approximately matches an arbitrary two pole, and has given the value of minimum reflection coefficient which may be obtained using an infinite ladder structure of reactance elements. The disadvantages of reactance matching networks are that they must result in a finite residual reflection, and are difficult to realize as distributed-parameter structures for use at microwaves. If loss can be tolerated, the constant-resistance networks discussed here are more suitable, since they give ideal reflectionless matching, and the relatively small number of elements they contain simplifies the problem of finding a final representation as a microwave structure

In order to proceed with the determination of a lumped ideal matching network, use is made of a property of driving-point network functions given by Bode.[7] This may be stated as follows: If $Y(s)$ is a rational, realizable driving-point admittance of the minimum-susceptance type, then a partial fraction expansion gives: ($Y(s)$ has only simple poles),

$$Y(s) = \pm G_0 + \sum_i \left(\frac{a_i s^2 + b_i s + c_i}{d_i s^2 + e_i s + f_i} + \frac{A_i s + B_i}{C_i s + D_i} \right), \tag{10}$$

where each term of the first summation represents a physically realizable biquadratic admittance function with one pair of complex conjugate poles, and each term of the second summation represents a physically realizable bilinear admittance function with a single real pole. In order to insure that all terms under the summation sign are positive real, it may be necessary to make the constant term G_0 negative. The network shown in Fig. 3(b) is always a possible representation of (10) for, since none of the terms, by hypothesis, can have poles on the imaginary s axis, a finite series resistance can be extracted from every shunt branch.[8]

[6] R. M. Fano, Technical Report No. 41, Research Laboratory of Electronics, MIT, January, 1948.

[7] See chap. 10, p. 200, of footnote reference 3.

[8] In case a term has a zero minimum value of conductance, it will be necessary to add some finite conductance extracted from G_0.

Thus the impedance of each branch is

$$Z_i = R_i + \overline{Z}_i. \tag{11a}$$

To form a constant-resistance network, a set of shunt circuits, as in Fig. 3(a), is added to the given structure. Each of these circuits has only positive elements and corresponds to one of the branches given by (11a) with an impedance

$$Z_{ic} = R_i + \overline{Z}_{ic} \tag{11b}$$

where $\overline{Z}_{ic}$ and $\overline{Z}_i$ are inverse networks;

$$\overline{Z}_{ic}\overline{Z}_i = R_i^2. \tag{11c}$$

The resultant structure has an input admittance which is a real positive constant, G_T, independent of the sign or magnitude of G_0. This follows from the fact that $Y(s)$ is a positive real function.

$$G_T = (\pm G_0 + \sum G_i) \geqq 0. \tag{12}$$

Other questions concerning the general case of Fig. 3(b), such as the possibility of eliminating mutual reactance, will not be treated here, but a special case which has found frequent application in design problems

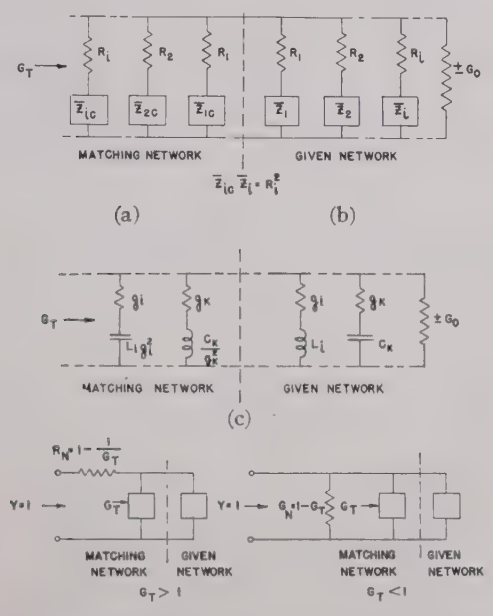


Fig. 3—General determination of ideal matching networks.

will be considered. If $Y(s)$ has only real poles, then the terms of the second degree in (10) are eliminated. The given network is then made up of shunt branches, each of which is of the series RL or RC type, plus one shunting resistor which may be negative. The input admittance is then of the form

$$Y(s) = \pm G_0 + \sum_i \left[\frac{1}{L_i}\,\frac{1}{s + \alpha_i}\right] + \sum_k \frac{g_k s}{s + \gamma_k} \tag{13}$$

where

$$\alpha_i = \frac{1}{g_i L_i}; \qquad \gamma_k = \frac{g_k}{C_k}. \tag{13b}$$

The matching procedure for this case is indicated in Fig. 3(c). If the impedances are all normalized to the line characteristic impedance, it is desired to have the ideal matching network produce a constant input resistance of 1.0. To do this, a single additional normalizing resistance R_N is used. If $G_T > 1$, as in Fig. 3(d), R_N is placed in series with the matching network and has a value

$$R_N = 1 - \frac{1}{G_T}. \tag{14a}$$

If $G_T < 1$, as in Fig. 3(e), R_N is placed in shunt with the matching network and has a value

$$R_N = \frac{1}{1 - G_T}. \tag{14b}$$

Fig. 4 shows the matching procedure for the two interpolating networks whose characteristics were shown in Figs. 1 and 2.

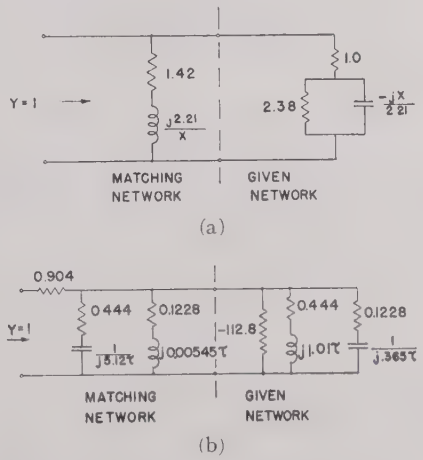


Fig. 4—Determination of ideal matching networks. (a) Infinite dissipative line. (b) Short-circuited dissipative line.

IV. Determination of the Microwave Structure

The final step in the design procedure is to find a distributed-parameter structure which will approximate the impedance characteristics of the ideal matching network over a specified frequency band. This problem is essentially the inverse of the original interpolating procedure. To obtain an indication of the order of magnitude of the mismatch produced by an impedance which deviates from the ideal matching network, the input voltage-standing-wave ratio may be calculated as a function of the admittance deviation between the microwave network and the ideal matching network. The input reflection factor is given by

$$K = \frac{1 - y}{1 + y} \tag{15}$$

where y is the normalized actual input admittance. But

$$y = y_a + y_e = y_a + y_m + \Delta y = 1 + \Delta y \tag{16}$$

where y_a is the normalized admittance of the originally specified microwave device, y_e is the admittance introduced by the final microwave equalizer, y_m is the admittance of the ideal matching network, and $\Delta y = y_m - y_e$. Substituting in (15),

$$K = \frac{\Delta y}{2 + \Delta y} \doteq \frac{\Delta y}{2} \tag{17}$$

where the approximation is valid for $\Delta y \ll 2$. The VSWR, η, is then given by

$$\eta = \frac{1 + |K|}{1 - |K|} \doteq \frac{2 + |\Delta y|}{2 - |\Delta y|} \doteq 1 + |\Delta y|. \tag{18}$$

The final approximation of (18) may be taken as a fair indication of the mismatch whenever $\eta < 1.30$.

An important point indicated by (18) is that the microwave equalizer may deviate from the ideal matching network by an amount of the order of 30 per cent of Z_0 without introducing an inordinate reflection. Thus, if a VSWR of 1.30 is permissible, an accurate determination of the final microwave structure is not necessary, unless an extremely large amount of equalization is required.

The first step in finding the microwave matching network is to choose the form of structure which is to be used. A variety of structures will usually be possible, and experience, coupled with some ingenuity on the part of the designer, will help in arriving at a practical choice. In this phase of the problem, the ideal matching network is an invaluable aid in suggesting the type of distributed-parameter structure which should be chosen.

Fig. 5 shows two simple microwave transmission lines with loss, which are extremely flexible as circuit elements, and hence are applicable to many problems as matching networks. Fig. 6 gives typical input-admittance curves of the short-circuited, uniformly dissipative line of Fig. 5 drawn for the entire frequency spectrum. It indicates quite clearly the wide range of admittance loci that it is possible to realize with this simple structure, and suggests how such a line may be used as a circuit element. More detailed characteristics are given by Crosby and Pennypacker.[9]

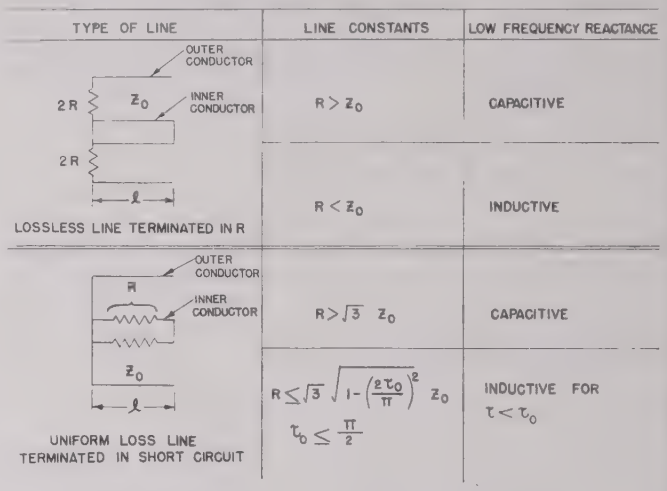


Fig. 5—Low-frequency response of coaxial lines.

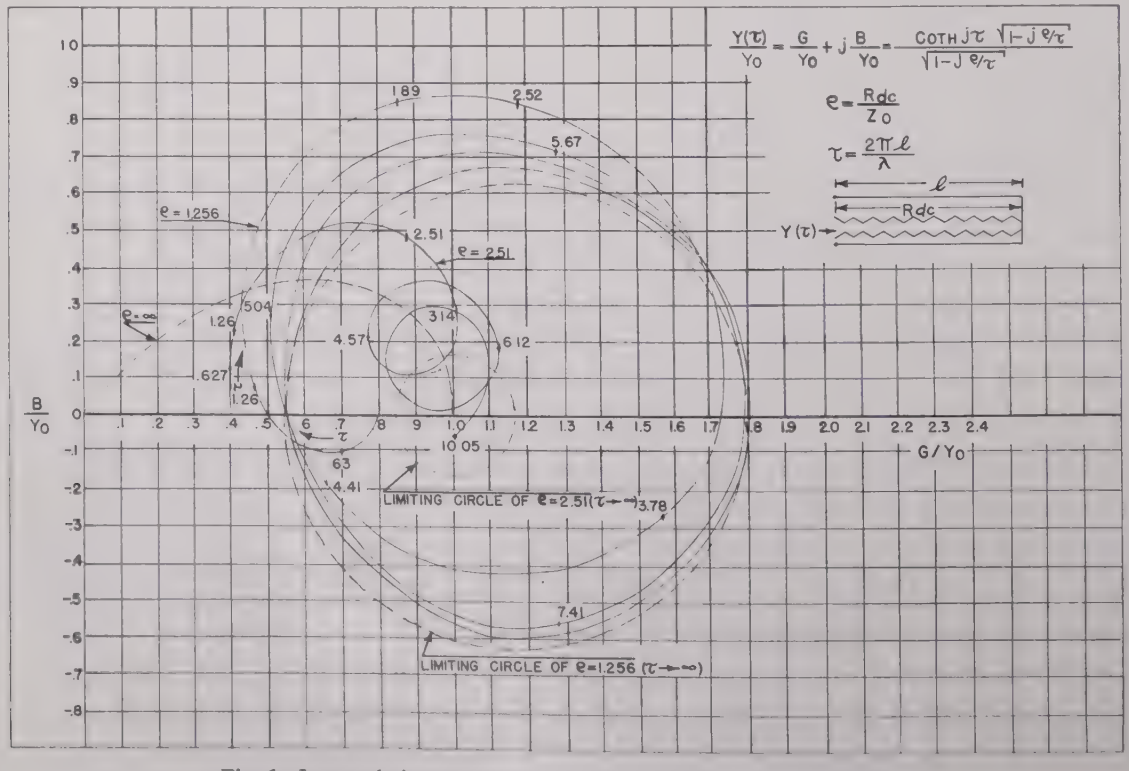


Fig. 6—Input admittance loci of short-circuited dissipative coaxial lines.

[9] D. R. Crosby and C. H. Pennypacker, "Radio-frequency resistors as uniform transmission lines," PROC. I.R.E., vol. 34, pp. 62–66; February, 1946.

The final problem is to determine quantitatively the constants of the chosen microwave structure so as best to approximate the ideal matching network. If the input admittance of the microwave device is given by

$$Y_e(s) = F(s, \Phi_1, \Phi_2, \cdots, \Phi_n) \tag{19}$$

where the Φj are the parameters such as termination, characteristic impedance, length, etc., which characterize the structure, then the solution for these parameters may be formally written down in terms of the method of least squares. This can be done if it is noted from (17) that the reflection factor K is proportional to Δy, so that the solution which minimizes $|K|^2$ over a specified frequency band may be expressed in terms of the square of the magnitude of the admittance deviation $|\Delta y|^2$. The result is the set of n simultaneous equations of the form

$$\int_{S_a}^{S_b} \left[(y_{er} - y_{mr}) \frac{\partial F_r}{\partial \Phi_j} + [y_{ei} - y_{mi}] \frac{\partial F_i}{\partial \Phi_j} \right] dq = 0 \tag{20}$$

$$j = 1, 2, \cdots, n$$

where the subscripts r and i, respectively, denote real and imaginary parts, and S_a and S_b are the band limits.

A direct solution of equations (20) is generally quite difficult, but a great deal of numerical simplification is possible.[10] In particular, these equations can be converted into a set of simultaneous linear algebraic equations in the unknowns Φj, provided it is possible to make a reasonable initial estimate of these quantities. In the example given below, a graphical method is used to obtain the approximate values of the microwave network constants, and, because a high degree of accuracy is not generally needed, as discussed earlier in connection with (18), these values are sufficiently good to make the use of (20) unnecessary. This is found to be true in many design problems, particularly when the ideal matching network does not have a large number of branches.

V. Application to the Design of Fixed Pad Coaxial Attenuators

As a typical example, the design procedure for a 20-db coaxial pad which is to operate over the frequency band 1000- to 4000-Mc (7.5 to 30 cm) will be described briefly. The given structure to be matched is chosen as a length of metallized glass whose resistance per unit length does not introduce excessive attenuation variation over the frequency band. This is easily accomplished but the details are not pertinent here and have been described elsewhere.[4] Initially the entire 20-db loss is assumed associated with this lossy line, but the finite loss of the matching network is taken care of in the final design by merely shortening the main attenuator insert by the requisite amount. Since the loss is high, the input impedance of the main attenuator insert is equal to its characteristic impedance, and is given by (6) .The two-point interpolation of Fig. 1 is quite adequate, since, corresponding to the choice of frequency range and attenuator insert constants, the value of X is well within the range of Fig. 1. The interpolating rational function is therefore given by (7), and the ideal matching network is formed according to Fig. 4(a).

A consideration of the ideal matching network, which is inductive, in conjunction with Figs. 5 and 6 suggests a short-circuited lossy stub line as the microwave matching structure. A graphical procedure is used to find the constants R_{dc}, Z_0, and l of the stub line shown in Fig. 2. First, the admittance of the ideal matching network is plotted. This is a circular locus in the $G-B$

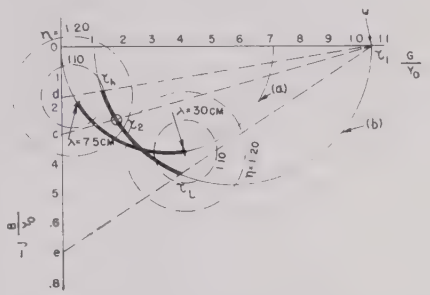


Fig. 7—Graphical determination of a microwave matching structure. Curve (a): Admittance locus of an ideal matching network. Curve (b): Approximate admittance locus of a microwave structure.

plane, and is shown as curve (a) of Fig. 7, with the terinal points corresponding to the band limits, $\lambda = 7.5$ cm

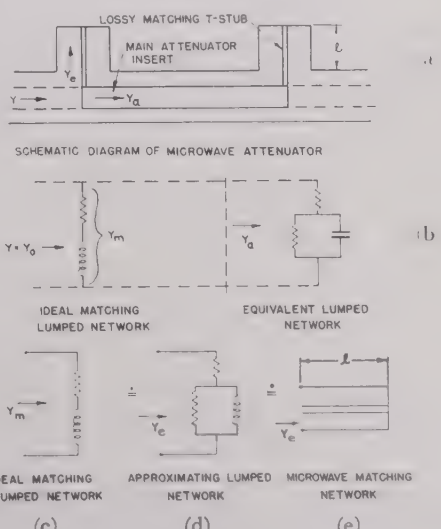


Fig. 8—Summary of design procedure for a 20-db "chimney" attenuator.

and $\lambda = 30$ cm, indicated. The constants of the stub line must now be chosen so that y_e, the admittance of the microwave network, approaches curve (a) over the specified band. To do this it is assumed that the stub line, whose admittance is given by (8), can be approximated over the 1000- to 4000-Mc frequency band, by a rational admittance function found from a two-point

[10] I. S. Sokolnikoff and E. S. Sokolnikoff, "Higher Mathematics for Engineers and Physicists," McGraw-Hill Book Co., New York, N. Y., 1934, p. 407.

interpolation process, i.e., a bilinear form similar to (7). This function is realized by a network of the type shown in Fig. 8(d), but the element values are unknown. However, a network of this type must have a circular admittance locus. Since (8) is a function of $\tau = 2\pi l/\lambda$, the length l has no effect on the shape of this locus, but only on the frequency scale of the curve. Hence, by drawing several loci corresponding to a few chosen values of R_{dc} and Z_0, the best locus curve can be found by comparing the resultant circles with curve (a). This gives two of the three required parameters, and, by graphically adjusting the scale, the third unknown, l, is found. The whole procedure is actually a very straightforward process, for the circular loci may be located and drawn very simply in the following way. Suppose specific values for R_{dc} and Z_0 have been chosen. Two interpolating points are taken, one being $\tau_1 = 0$, the other some assumed value of τ_2 in the neighborhood of $2\pi l/\lambda = 0.4\pi$; i.e., in order that Y_e be inductive, τ_2, according to Fig. 5, is chosen $\tau_2 < \tau_0 < (\pi/2)$. The values of $Y_e(s)$ are calculated from (7):

$$Y_e(s)\,|_{\tau=0} = \rho = \frac{R}{Z_0} \tag{21a}$$

$$Y_e(s)\,|_{\tau=\tau l} = g_{e_2} + jb_{e_2} \tag{21b}$$

where g_{e_2} and b_{e_2} will now have some definite numerical value. These two points are plotted, and, since the center of the circle must lie on the real axis, the entire circular locus may be immediately constructed. In this manner curve (b) of Fig. 7 was chosen (other circles are left out for the sake of clarity) from a number of circles; R_{dc} and Z_0, associated with this curve, are thus determined. It is now necessary to fix the terminal points of the (b) locus curve. Only one of these can be chosen independently. In Fig. 7, the high-frequency terminal point τ_h is chosen on curve (b) to lie as close as possible to the point $\lambda = 7.5$ cm of curve (a). To find the value of τ_h, a simple geometric property of the linear transformation is used.[11] Referring to the construction lines on Fig. 7,

$$\tau_h = \tau_2 \frac{\overline{Oc}}{\overline{Od}}, \tag{22a}$$

and l is given by

$$l = \lambda \cdot \frac{\tau_h}{2\pi} = 7.5 \times \frac{\tau_h}{2\pi}. \tag{22b}$$

In a similar fashion, a point corresponding to any wavelength may now be located on curve (b). For example, for the low-frequency limit at 30 cm,

$$\tau = \tau_L = \tfrac{1}{4}\tau_h,$$

and the construction line $\overline{Qe}$, with $\overline{Oe} = 4\ \overline{Od}$, locates the point on curve (b) corresponding to τ_L. On the basis of (18), the VSWR circles shown in Fig. 7 are drawn, and these indicate the mismatch which may be expected.

[11] C. W. Carter, "Graphic representation of the impedance of resistance networks containing two reactances," *Bell Sys. Tech. Jour.*, vol. 4, pp. 387–402; July, 1925.

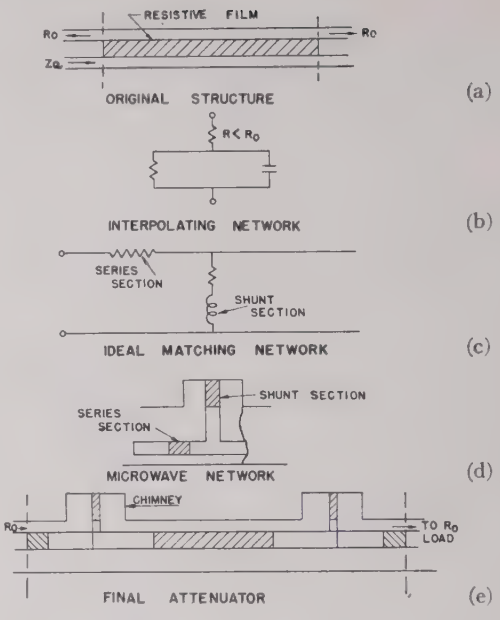


Fig. 9—Summary of design procedure for a 10-db "chimney" attenuator.

Fig. 8 summarizes the procedure described for the 20-db attenuator, and Fig. 9 shows the steps in the design of a 10-db unit for the frequency band 0 to 1000 Mc. Attenuators of this type have become known as "chimney attenuators" from the appearance of the stub lines. Although space does not permit discussion here, it is possible to utilize the matching networks for attenuation equalization as well as matching. The experimentally measured performance curves of Fig. 9 for a 10-db and 20-db chimney attenuator are for typical designs which have been matched as described in this paper, and designed as well for attenuation equalization.

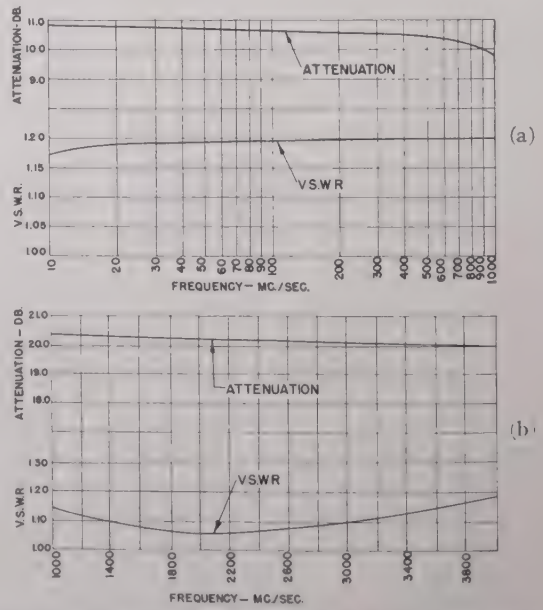


Fig. 10—Typical measured characteristics of chimney attenuators (a) 10-db, $\frac{7}{8}$-inch line unit, 0–1000 Mc. (b) 20-db, $\frac{7}{8}$-inch line unit, 1000–4000 Mc.

Analysis of a Wide-Band Waveguide Filter*

SEYMOUR B. COHN†, MEMBER, IRE

Summary—A rectangular-waveguide structure consisting of a series of constrictions and cavities is analyzed and shown to have the properties of a wide-band filter. The lower cutoff of the lowest-frequency pass band is due to the natural cutoff behavior of the waveguide itself. The upper cutoff of this band is due to the succession of discontinuities. Under the assumption of no dissipation in the filter sections, exact equations for the image parameters of the filter are derived. These equations take full account of the discontinuities and their interaction.

As a by-product of this analysis, formulas are obtained for the exact equivalent circuits of three rectangular-waveguide structures: (a) a cavity formed by two changes in height (Fig. 2(a)); (b) an increase of height followed by a short-circuiting wall (Fig. 2 (b`)); (c) the hypothetical case of an increase of height followed by an open-circuiting wall (Fig. 2 (c`)). It is shown how the analysis of structure (b) may be used to obtain an improved solution for ridge waveguide.

The writer will cover the more practical problems of filter design and experimental verification in another paper.

THE FILTER structure that is analyzed in this paper is shown in Fig. 1.[1] Design relations are given for it in the literature,[2] for $b \leqq l$. In this paper, the more useful case of b unrestricted is treated. It is assumed that the conductance of the metallic walls is infinite.

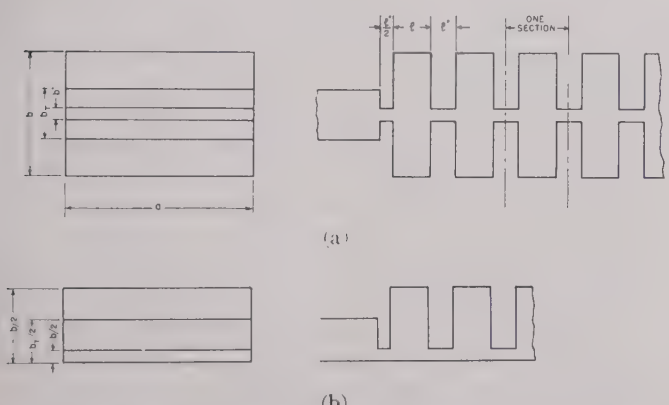


Fig. 1—The waveguide filter structure studied in this paper. Because of symmetry considerations, the theory developed for (a) applies to (b).

Basic Principles

Waveguide is considered from the transmission-line standpoint in this paper.[3,4] The *impedance* at a given reference plane is defined as

$$Z = -C\frac{bE_y}{aH_x}, \tag{1}$$

where C is an arbitrary constant, a is the width, and b the height of the guide, and E_y, H_x are the transverse electric and magnetic field strengths at a given point in the reference plane. The *characteristic impedance* of the guide is

$$Z_o = \frac{Cb\eta}{a\sqrt{1-(f_c/f)^2}} \tag{2}$$

where η is the characteristic impedance of free space (377 ohms if mks units are used), f_c the cutoff frequency of the TE_{10} mode, f the frequency of operation, and C the same constant as in (1).

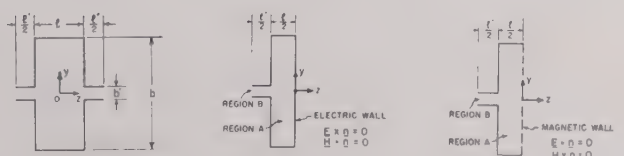
The guide wavelength λ_g is given in terms of the space wavelength λ by

$$\lambda_g = \frac{\lambda}{\sqrt{1-(f_c/f)^2}}. \tag{3}$$

The image parameters of classical filter theory may be used with wave-guide filters, as explained in the literature.[5] In Fig. 1 it is shown how the waveguide filter may be split up into identical sections. Let Y_{sc} and Y_{oc} be the short-and open-circuit admittances of a filter half section (Fig. 2). Then the image admittance Y_I and image transfer constant θ of a full section are given by

$$Y_I = \sqrt{Y_{sc}Y_{oc}} \tag{4}$$

$$\tanh\frac{\theta}{2} = \sqrt{\frac{Y_{oc}}{Y_{sc}}}. \tag{5}$$



(a) (b) (c)

Fig. 2.—A single filter section (a); a short-circuited half section (b); an open-circuited half section (c).

For a nondissipative filter, Y_I is real in pass bands and imaginary in stop bands. θ is imaginary in passbands and real in stop bands. θ is usually written

$$\theta = \alpha + j\beta, \tag{6}$$

where α is the the image attenuation constant in nepers, and β the image phase constant in radians.

* Decimal classification: R118.1. Original manuscript received by the Institute, July 2, 1948; revised manuscript received, November 19, 1948. Presented, 1948 National IRE Convention, March 23, 1948, New York, N. Y.

† Sperry Gyroscope Company, Great Neck, L. I., N. Y.

[1] Filter configurations of this and other types have been proposed by numerous investigators before the war. In order to keep the length of this paper within reasonable bounds, a history of waveguide filters is omitted.

[2] Radio Research Laboratory Staff, "Very High-Frequency Techniques," McGraw-Hill Book Co., New York, N. Y., section 27–28; 1947.

[3] S. A. Schelkunoff, "The impedance concept and its application to problems of reflection, refraction, shielding and power absorption," *Bell Sys. Tech. Jour.*, vol. 17, pp. 17–49; January, 1938.

[4] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand, Inc., New York, N. Y., pp. 319–320, 490–494; 1943.

[5] See chapter 26 of footnote reference 2.

Fig. 3 shows the kind of Y_{oc} and Y_{sc} functions that one obtains for a waveguide filter half section. The independent variable is the inverse guide wavelength $1/\lambda_g$, which is analogous to frequency in ordinary transmission-line filters. The corresponding Y_I, α, and β functions for this case are sketched in Fig. 3, also. Note that there is a succession of pass bands, but the first and second pass bands are separated by a wide stop band. In an actual filter design, only the first pass band is usually used. The next pass band begins near the frequency for which $\lambda_g = b$.

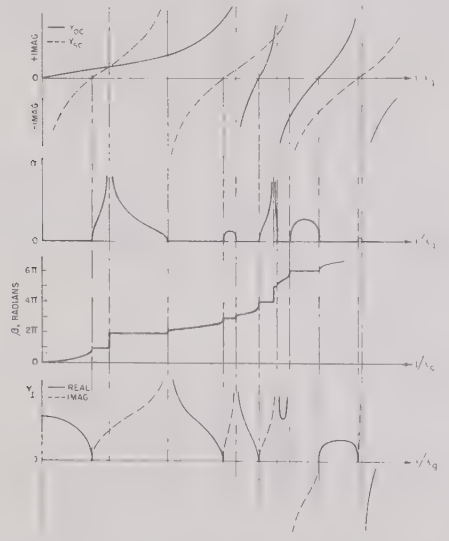


Fig. 3—Open- and short-circuit admittances of a typical half-section filter. The image parameters of the corresponding full section are also shown.

Theoretical Analysis

The field in each uniform region of the filter may be represented by a superposition of all the modes possible in that region. The boundary conditions at the conductors parallel to the z axis will be met automatically by the use of the characteristic modes of the waveguide

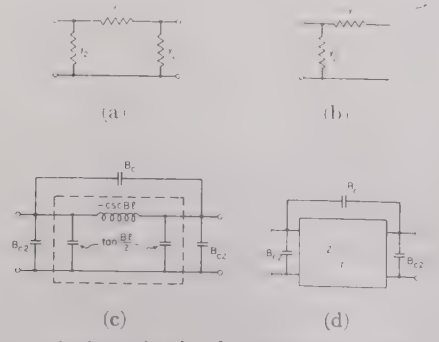


Fig. 4—The equivalent circuit of a waveguide filter section. The capacitances and inductances are, of course, functions of frequency.

cross section. On the conducting surfaces perpendicular to the z axis (Fig. 2), and at the boundaries between the different regions, the boundary conditions are met by the proper choice of amplitude and phase for each mode. The electric and magnetic fields at each point inside the filter will then be expressed by an infinite series of mode terms. If these series are everywhere convergent, and satisfy all boundary conditions, then they will be the true solution of the field problem. The equivalent circuit or the image parameters of the filter may be calculated once the field is known.

There are several possible methods of carrying out such a solution for this filter. For the waveguide filter, Hahn's method[6] is easily applicable and fairly straightforward, and hence is used in this report. It gives an entirely adequate and sufficiently accurate solution of the filter problem. Schwinger's *variational* method might also have been used. This method is covered in Radiation Laboratory lecture notes,[7] and in a paper by Miles.[8]

Examination of Fig. 1 shows that, except for the ends, the filter consists of a periodic composition of two different shapes, one of length and height l and b, the other of length and height l' and b'. It may be shown that the discontinuities at the ends of the l' lengths are virtually isolated from each other for any value of l'/b'. The interaction through the lengths l' will therefore be neglected, especially since, in most filter designs, l'/b' is greater than or equal to one. Because of this, the filter may be divided into sections as shown in Figs. 1 and 2(a). Each section is independent of the adjacent ones or of the terminating guide, as far as higher mode coupling is concerned.

A possible method of obtaining the filter-section parameters Y_I and θ that immediately suggests itself is as follows: (a) calculate the field inside the filter by Hahn's method for the two cases of an open and short circuit at the plane $z=0$; (b) calculate the open-circuit and short-circuit admittances for the fundamental mode at the plane $z=-(l+l')/2$ through the use of (1); (c) then calculate Y_I and θ by means of (4) and (5).

The waveguide structure of Fig. 1 is excited by a TE_{10}-mode wave, which has a half-sine-wave variation of field in the x direction. Since the surface of the filter structure is cylindrical in the x direction, with shorting planes at $x=\pm a/2$, there is nothing in the filter that can excite higher modes with more than a half-wave x-direction variation. The filter discontinuities will, however, excite modes having variations in the y direction, although the TE_{10} mode has none. Because of the y axis symmetry, only modes which have $2n$ half-wave variations in this direction are excited. That is, only $TE_{1,2n}$ and $TM_{1,2n}$ modes can exist ($n=0, 1, 2, 3, \cdots$). The TE higher modes are needed to provide at the x-y-plane

[6] W. C. Hahn, "A new method for the calculation of cavity resonators," *Jour. Appl. Phys.*, vol. 12, p. 62; 1941.
[7] D. S. Saxon, "Notes on Lectures by Julian Schwinger—Discontinuities in Wave Guides," MIT Radiation Laboratory Theoretical Group, February, 1945.
[8] J. W. Miles, "The equivalent circuit for a plane discontinuity in a cylindrical wave guide," Proc. I.R.E., vol. 34, pp. 728–743; October, 1946.

conducting surfaces an H_z field which will cancel the H_z component of the TE_{10} mode. The TM higher modes are needed in order to provide an E_z component for the fringing electric field which must exist at these same conductors.

Consider the region of height b and length l in Fig. 2(a). The origin of the x, y, z co-ordinate system is taken at the center of this region. Owing to reflections at both ends, there will be waves of all possible modes traveling in both the plus and minus z direction. That is, there will be a set of modes multiplied by $e^{-\gamma_n z}$, and a set multiplied by $e^{+\gamma_n z}$. The total field may, therefore, be written as a set of modes multiplied by $\sinh \gamma_n z$, plus a set multiplied by $\cosh \gamma_n z$.

The problem can be simplified at this point if one recognizes that an E_x component of field can not be excited by this filter structure. Since both the $TE_{1,2n}$ and $TM_{1,2n}$ modes have E_x components for n greater than zero, one must choose a linear combination of these modes for each value of n such that E_{xn} is canceled. When this is done, the following field relations result for the nth mode. The time dependence factor $e^{j\omega t}$ is understood.

$$E_{yn} = \cos k_x x \cos k_{yn} y \, (C_n \sinh \gamma_n z + D_n \cosh \gamma_n z) \quad (7)$$

$$E_{xn} = \frac{j4\pi^2}{\eta k \gamma_n \lambda_g^2} \cos k_x x \cos k_{yn} y (C_n \cosh \gamma_n z + D_n \sinh \gamma_n z) \quad (8)$$

$$E_{zn} = \frac{k_{yn}}{\gamma_n} \cos k_x x \sin k_{yn} y (C_n \cosh \gamma_n z + D_n \sinh \gamma_n z) \quad (9)$$

$$H_{zn} = \frac{-jk_x}{\eta k} \sin k_x x \cos k_{yn} y (C_n \sinh \gamma_n z + D_n \cosh \gamma_n z) \quad (10)$$

$$H_{yn} = \frac{jk_x k_{yn}}{\eta k \gamma_n} \sin k_x x \sin k_{yn} y (C_n \cosh \gamma_n Z + D_n \sinh \gamma_n Z) \quad (11)$$

where $k_x = \pi/a$, $k_{yn} = 2\pi n/b$, $k = 2\pi/\lambda$, $\gamma_n = \sqrt{k_x^2 + k_{yn}^2 - k^2}$, λ_g = guide wavelength of the TE_{10} mode, and $\eta = 120\pi$ ohms.

Equations (7) to (11) give the complete field in the region bounded by $x = \pm a/2$, $y = \pm b/2$, and $z = \pm l/2$. The boundary conditions on the surfaces parallel to the z axis are automatically satisfied for each value of n. On the transverse surfaces at $z = \pm l/2$, the boundary conditions will be met through the choice of a proper superposition of modes for all values of n from zero to infinity. In addition, since $E_x = E_z = H_y = 0$ for $y = 0$, the same field that satisfies Fig. 1(a) will also satisfy Fig. 1(b).

The advantage of solving the half sections of Fig. 2 separately is now apparent, since for the short-circuit case, D_n is zero, while for the open-circuit case, C_n is zero.

It can be shown that if the total components $E_y = \sum E_{yn}$ and $H_z = \sum H_{zn}$ are matched at the boundary plane, then the other total components must also be matched.[9] In the Appendix the matching of E_y and H_z is partly carried out for the short-circuited half section. The open-circuit case is similar and the derivation is therefore omitted. The open- and short-circuit admittances at $z = -l/2$ normalized with respect to the guide of height b are:

$$y_{oc} = j \tan \frac{\beta l}{2} + j \frac{2b}{\lambda_g} \left\{ \frac{S_0(\delta)}{\pi^2} + \sum_{n>0} \left[\frac{\tanh \frac{n\pi l F}{b}}{F} - 1 \right] \frac{\sin^2 \pi n \delta}{n(\pi n \delta)^2} \right\} + j\epsilon_{oc} \quad (12)$$

$$y_{sc} = -j \cot \frac{\beta l}{2} + j \frac{2b}{\lambda_g} \left\{ \frac{S_0(\delta)}{\pi^2} + \sum_{n>0} \left[\frac{\coth \frac{n\pi l F}{b}}{F} - 1 \right] \frac{\sin^2 \pi n \delta}{n(\pi n \delta)^2} \right\} + j\epsilon_{sc} \quad (13)$$

where

$$F = \sqrt{1 - \left(\frac{b}{n\lambda_g} \right)^2}. \quad (14)$$

In these equations, $\beta = 2\pi/\lambda_g$, λ_g is the guide wavelength of the TE_{10} mode, $\delta = b'/b$, ϵ_{oc} and ϵ_{sc} are correction terms. Zero dissipation is assumed. $S_0(\delta)$ is the Hahn function of zero order. It is tabulated by Whinnery and Jamieson.[10] Their value for $\delta = 0.05$ is in error, however, and should be $S_0(0.05) = 26.23$.

The evaluation of the correction terms ϵ_{oc} and ϵ_{sc} is carried out in reference 9, but is omitted here because it is tedious and lengthy. Fortunately, for the usual filter case of δ small, the correction terms are also small, and may be closely approximated by

$$\epsilon_{oc} \approx -0.09 \frac{b}{\lambda_g} \approx \epsilon_{sc}. \quad (15)$$

More accurate values are given by (42) and (43).

The first term on the right side of (12) is the input admittance of an open-circuited line of length $l/2$ and characteristic admittance unity. The second term is a capacitive susceptance effectively shunted across the input of this line. The same remarks apply to (13), except that here the first term is the admittance of a shorted line.

If in either (12) or (13), l is made indefinitely large, the capacitive susceptance term becomes that of a sin-

[9] S. B. Cohn, "A Theoretical and Experimental Study of a Waveguide Filter Structure," Office of Naval Research, Cruft Laboratory, Harvard University, Report No. 39, April 25, 1948; also, same title, doctorate thesis, Department of Engineering Science and Applied Physics, Harvard University, 1948.

[10] J. R. Whinnery and H. W. Jamieson, "Equivalent circuits for discontinuities in transmission lines," Proc. I.R.E., vol. 32, pp. 98-115; February, 1944.

gle isolated step discontinuity. Several values of this normalized susceptance B_c/Y_0 have been calculated for $\delta=0.1$ and are compared with values calculated from

TABLE I

b/λ_g	*WGHB* Equation	Equation (12) or (13)
0	3.84	3.85
0.6	4.36	4.38
0.9	6.41	6.48

the "Wave-Guide Handbook," formula.[11] Values of the quantity $B_c\lambda_g/Y_0b$ are given in Table I. The agreement is very good even for b/λ_g equal to 0.9, despite the fact that the series in (13) and in ϵ_{sc} do not converge in the close vicinity of $b/\lambda_g=1$. Even for δ as large as 0.5 (12) or (13) and (15) are only 3 per cent less than the exact value for $b/\lambda_g=0$ and l infinite. If the more accurate correction-term formula of (42) or (43) is used, the error is reduced to one per cent.

The equivalent circuit of the double discontinuity will now be developed. Any symmetrical two-terminal-pair network or waveguide structure has the equivalent circuit shown in Fig. 4(a). The half-structure equivalent circuit is shown in Fig. 4(b). From this one sees that

$$y_{oc} = y_2, \qquad y_{sc} = y_2 + 2y_1$$

or

$$y_2 = y_{oc}, \qquad y_1 = (y_{sc} - y_{oc})/2. \tag{16}$$

On applying these to (12) and (13), one obtains

$$y_2 = j\tan\frac{\beta l}{2} + jB_{C2} \tag{17}$$

$$y_1 = -\frac{j}{2}\left(\cot\frac{\beta l}{2} + \tan\frac{\beta l}{2}\right) + jB_{C1}$$

$$= -j\csc\beta l + jB_{C1} \tag{18}$$

where

$$B_{C2} = \frac{2b}{\lambda_g}\left\{\frac{S_0(\delta)}{\pi^2} + \sum_{n>0}\left[\frac{\tanh\dfrac{n\pi l/F}{b}}{F} - 1\right]\frac{\sin^2\pi n\delta}{n(\pi n\delta)^2}\right\} + \epsilon_{oc} \tag{19}$$

$$B_{C1} = \frac{2b}{\lambda_g}\sum_{n>0}\frac{\operatorname{csch}\dfrac{2\pi nl/F}{b}}{F}\,\frac{\sin^2\pi n\delta}{n(\pi n\delta)^2} + \frac{\epsilon_{sc}-\epsilon_{oc}}{2}. \tag{20}$$

For the range of guide wavelength of interest here, B_{C1} and B_{C2} are capacitive susceptances, and $\tan(\beta l/2)$ and $\csc\beta l$ are positive functions which are roughly proportional to $1/\lambda_g$ and λ_g, respectively. The equivalent circuit of the portion of Fig. 2(a) between the planes $z=\pm l/2$ may therefore be drawn as shown in Fig. 4(c). Note that all element values shown on this circuit are susceptances normalized with respect to the characteristic admittance of the waveguide line of height b. A complete filter section will have a short length of guide of height b' and length $l'/2$ at each end. The principal effect of this is to add additional shunt capacitance to the equivalent circuit. The inverse guide wavelength for the waveguide filter is seen to be analogous to frequency for the equivalent low-frequency circuit. Since the circuit is that of an m-derived low-pass filter, one may expect the waveguide filter to have characteristics similar to its low-frequency equivalent, except for the change in the frequency scale. Note that without the bridging susceptance B_{C1}, the infinite-attenuation point found with the waveguide filter could not exist.

The portion of Fig. 4(c) within the dotted line is the exact equivalent of a transmission line of length l and characteristic admittance unity. Hence the equivalent circuit of the double discontinuity may be drawn as in Fig. 4(d). (The last circuit is a symbolic one which must be redrawn as in Fig. 4(c) before it can be used.)

The Filter Relations

The values of y_{oc} and y_{sc} given in (12) and (13) are for $l'=0$. If the symbols y_{oc} and y_{sc} are now applied to a filter half section having l' greater than zero, and y_{oc}' and y_{sc}' to the case of l' equal to zero, then the actual half-section open- and short-circuit admittances are

$$y_{oc} = jY_{02}\tan\left[\frac{\pi l'}{\lambda_g} + \tan^{-1}\left(\frac{Y_{01}y_{oc}'}{Y_{02}j}\right)\right]$$

$$y_{sc} = jY_{02}\tan\left[\frac{\pi l'}{\lambda_g} + \tan^{-1}\left(\frac{Y_{01}y_{sc}'}{Y_{02}j}\right)\right].$$

(These equations may be derived from King, Mimno, and Wing.[12]) But $Y_{01}/Y_{02}=b'/b=\delta$, and Y_{01} was set equal to one in the last section. Therefore,

$$y_{oc} = \frac{j}{\delta}\tan\left[\frac{\pi l'}{\lambda_g} + \tan^{-1}\left(\frac{\delta y_{oc}'}{j}\right)\right] \tag{21}$$

$$y_{sc} = \frac{j}{\delta}\tan\left[\frac{\pi l'}{\lambda_g} + \tan^{-1}\left(\frac{\delta y_{sc}'}{j}\right)\right] \tag{22}$$

where y_{oc} and y_{sc} are normalized with respect to a guide of height b. y_{oc}' and y_{sc}' are obtained from (12) and (13). The image parameters of the filter section may now be calculated by means of (4), (5), (21), and (22).

The upper cutoff of the principal pass band occurs for the first zero of (22), since the image admittance changes from real to imaginary at that point. Let λ_{g1} be the value of λ_g at the upper cutoff frequency. Equation (22)

[11] "Wave-Guide Handbook, First Revised Edition," Radiation Laboratory Report No. 43, February 7, 1944. Also, N. Marcuvitz, "Wave-Guide Handbook," Radiation Laboratory Series, vol. 10, McGraw-Hill Book Co. New York, N. Y., to be published.

[12] R. W. P. King, H. R. Mimno, and A. H. Wing, "Transmission Lines, Antennas, and Wave Guides," McGraw-Hill Book Co., New York, N. Y., 1945.

is zero for

$$\tan \frac{\pi l'}{\lambda_{g1}} + \frac{\delta y_{sc}'}{j} = 0. \tag{23}$$

It is seen from (5) that the infinite-attenuation point occurs for $y_{sc} = y_{oc}$.

In Fig. 5 are shown typical image-admittance, phase-constant, and attenuation-constant curves. Inspection of the image-admittance curve shows that it follows the low-frequency constant-k image-admittance function very closely in the pass band. The latter function is given by

$$y_I = y_{I0}\sqrt{1 - (f/f_1)^2} \tag{24}$$

where y_{I0} is the value of image admittance at zero frequency and f_1 is the cutoff frequency. The variable f for the low-frequency filter is, of course, the analog of b/λ_g for the waveguide filter, and f_1 corresponds to b/λ_{g1}.

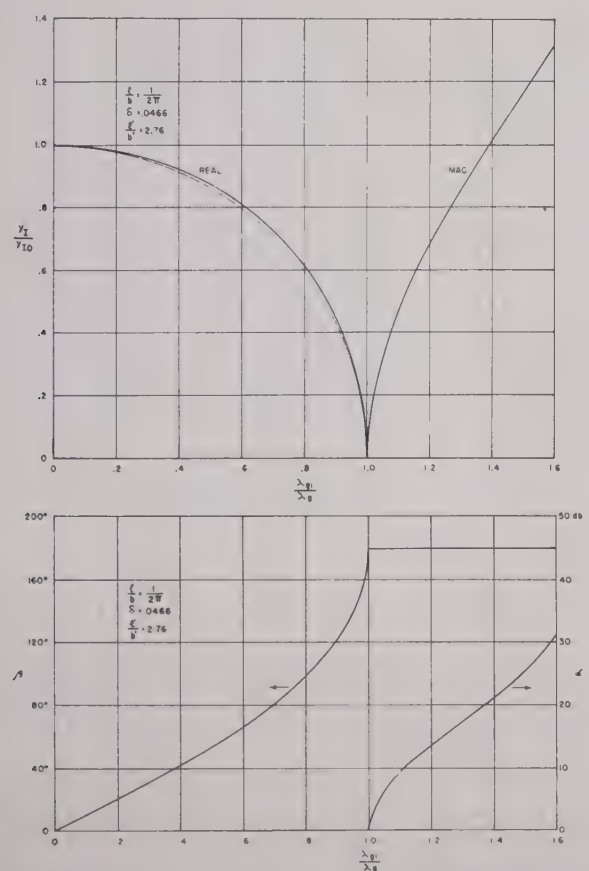


Fig. 5—Image parameters of a filter section. The image admittance of a low-frequency shunt-terminated constant-k filter is shown as a dashed curve.

Because of the fact that the waveguide-filter image admittance is very nearly independent of the filter parameters, one may match dissimilar sections with very little error by merely making their cutoff frequencies and the zero-frequency image admittance referred to the terminating lines the same. This makes it possible to design a filter to have sections with different values of infinite-attenuation wavelength, so as to obtain a sharp cutoff characteristic, and maintain high attenuation far into the stop band. This procedure is common in the design of low-frequency filters.

In a paper now under preparation, the author will show how the above analysis may actually be used in the design of practical filters, and a set of design curves will be presented which will obviate the use of the complicated relations given here. Such matters as matching, spurious responses, etc., will be taken up. Tests will be described which have shown that the analysis and design procedure may be relied on to give cutoff and infinite-attenuation frequencies within one or two per cent.

Application to Ridge Waveguide

The solution of the double discontinuity of Fig. 2(a) and of the two subcases of a single discontinuity in a waveguide terminated by an electric wall and by a magnetic wall (Figs. 2(b) and 2(c)) should find uses other than the application to the waveguide filter. One such use will now be described.

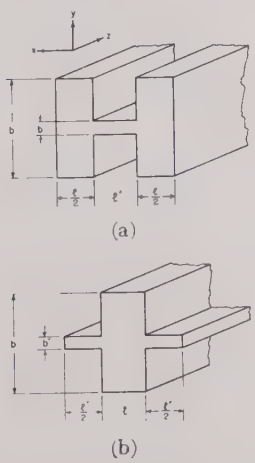


Fig. 6—Waveguide cross sections whose properties may be deduced from the waveguide-filter solution.

Fig. 6(a) shows the cross section of symmetrical ridge waveguide. The *approximate* cutoff frequency and characteristic impedance of ridge waveguide has been derived and presented graphically.[13] It will now be shown that the analysis in this article can be extended to give a more exact solution for ridge waveguide.

At the cutoff frequency, one may regard the field distribution in ridge guide as due to waves traveling transversely in the plus and minus x direction. If the structure of Fig. 6(a) is compared with that of Fig. 2(b), it is seen that the ridge-guide cross section has the shape of two short-circuited filter half sections joined together. At the cutoff frequency of the fundamental mode in ridge waveguide, the ratio H_z/E_y must be zero at the center of the cross section (see reference 13). Hence this

[13] S. B. Cohn, "Properties of ridge wave guide," Proc. I.R.E., vol. 35, pp. 783–789; August, 1947.

condition corresponds to $y_{sc}=-H_x/E_y=0$ for the filter half section, which is the condition for cutoff of the waveguide filter. The wavelength at which ridge waveguide cuts off is, therefore, the same as that at which the corresponding filter structure cuts off. This is given by the root of (23) with λ_g set equal to space wavelength λ. Since the filter analysis can give the field components in ridge guide, it is also possible to calculate the exact characteristic inpedance.

In a similar way, the exact cutoff frequency and characteristic impedance of the cross section shown in Fig. 6(b) might be derived from the open-circuit half-section case of Fig. 2(c).

Acknowledgment

The writer wishes to acknowledge the many helpful suggestions of R. W. P. King and L. Brillouin.

Appendix

For the short-circuit case of Fig. 2(b), set $D_n=0$ in (7) to (11). Then, with $x=0$ and $z=-l/2$, the nth-mode field in region A is

$$E_{yn} = -C_n \cos k_{yn}y \sinh \gamma_{An}l/2 \tag{25}$$

$$H_{xn} = \frac{j4\pi^2 C_n}{\eta k \gamma_{An}\lambda_g^2} \cos k_{yn}y \cosh \gamma_{An}l/2. \tag{26}$$

The other field components are zero for $x=0$.

The total region-A field for $x=0$ and $z=-l/2$ may be written as

$$E_{yA} = R_0 + \sum_{n>0} R_n \cos \frac{2\pi n y}{b} \tag{27}$$

$$H_{xA} = w_{A0}R_0 + \sum_{n>0} w_{An}R_n \cos \frac{2\pi n y}{b}, \tag{28}$$

where

$$R_0 = -jC_0 \sin (\beta l/2) \tag{29}$$

$$R_n = -C_n \sinh (\gamma_{An}l/2), \quad n>0 \tag{30}$$

$$w_{A0} = jy_0 \cot (\beta l/2) \tag{31}$$

$$w_{An} = -y_{An} \coth (\gamma_{An}l/2) \tag{32}$$

$$y_0 = \lambda/\eta\lambda_g \tag{33}$$

$$y_{An} = \frac{j4\pi^2}{\eta k \gamma_{An}\lambda_g^2} \tag{34}$$

$$\beta = 2\pi/\lambda_g \tag{35}$$

$$\gamma_{An} = \sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{2\pi n}{b}\right)^2 - \left(\frac{2\pi}{\lambda}\right)^2}. \tag{36}$$

y_0 is the characteristic wave admittance of the TE_{10} mode; y_{An} is the characteristic wave admittance of the higher composite TE-TM modes; w_{A0} and w_{An} are the negative of the wave admittances for the fundamental and higher modes at $z=-l/2$—that is, they are the ratio $+H_{zn}/E_{yn}$ for the region-A fields at that plane.

For the B region, one may write

$$E_{yB} = B_0 + \sum_{n>0} B_n \cos \frac{2\pi n y}{b'} \tag{37}$$

$$H_{xB} = w_{B0}B_0 + \sum_{n>0} y_{Bn}B_n \cos \frac{2\pi n y}{b'} \tag{38}$$

where

$$y_{Bn} = \frac{j4\pi^2}{\eta k \gamma_{Bn}\lambda_g^2} \tag{39}$$

$$\gamma_{Bn} = \sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{2\pi n}{b'}\right)^2 - \left(\frac{2\pi}{\lambda}\right)^2}. \tag{40}$$

w_{B0} is the negative of the TE_{10} wave admittance in region B, referred to the plane $z=-l/2$. Since this wave admittance is the short-circuit wave admittance w_{sc} for the half-section, one may write

$$w_{sc} = -w_{B0}. \tag{41}$$

The characteristic admittance in guide B is δ times that of guide A, and hence the normalized short-circuit admittance *referred to guide A* is $w_{sc}/\delta y_0$, which will be defined as y_{sc}.

E_{yA} is next set equal to E_{yB}, and H_{xA} is set equal to H_{xB}. From these relations, the mode amplitudes and w_{sc} may be determined. The method used is that of Hahn,[6] and the work is similar to that of Whinnery and Jamieson for a capacitive step in a parallel-plane transmission line.[10] For the sake of brevity, the remainder of this analysis is omitted. The derivation of y_{oc} is similar to that of y_{sc}, and is therefore omitted entirely.

The exact evaluation of ϵ_{sc} and ϵ_{oc} requires the solution of an infinite set of linear equations having an infinite number of unknowns. Good approximations for ϵ_{sc} and ϵ_{oc} are[9]

$$\epsilon_{sc} \approx -0.0417 \frac{b}{\lambda_g} \sum_{m>0} \frac{[L_m(\delta)]^2}{m^3} \tag{42}$$

$$\epsilon_{oc} \approx -0.0417 \frac{b}{\lambda_g} \sum_{m>0} \frac{[T_m(\delta)]^2}{m^3} \tag{43}$$

where

$$T_m(\delta) = S_m(\delta) + \sum_{n>0} \left\{ \frac{\tanh \frac{n\pi lF}{b}}{F} - 1 \right\} \frac{\sin^2 \pi n\delta}{n\left[\left(\frac{n\delta}{m}\right)^2 - 1\right]} \tag{44}$$

$$L_m(\delta) = S_m(\delta) + \sum_{n>0} \left\{ \frac{\coth \frac{n\pi lF}{b}}{F} - 1 \right\} \frac{\sin^2 \pi n\delta}{n\left[\left(\frac{n\delta}{m}\right)^2 - 1\right]} \tag{45}$$

$S_m(\delta)$ is a Hahn function defined and tabulated in reference 6. For δ small, (15) is usually a satisfactory approximation for (42) and (43).

Correspondence

Notes on Digital Coding*

The consideration of message coding as a means for approaching the theoretical capacity of a communication channel, while reducing the probability of errors, has suggested the interesting number theoretical problem of devising lossless binary (or other) coding schemes serving to insure the reception of a correct, but reduced, message when an upper limit to the number of transmission errors is postulated.

An example of lossless binary coding is treated by Shannon[1] who considers the case of blocks of seven symbols, one or none of which can be in error. The solution of this case can be extended to blocks of 2^n-1-binary symbols, and, more generally, when coding schemes based on the prime number p are employed, to blocks of $p^n-1/p-1$ symbols which are transmitted, and received with complete equivocation of one or no symbol, each block comprising n redundant symbols designed to remove the equivocation. When encoding the message, the n redundant symbols x_m are determined in terms of the message symbols Y_k from the congruent relations

$$E_m \equiv X_m + \sum_{k=1}^{k=(p^n-1)/(p-1)-n} a_{mk} Y_k \equiv 0 \pmod{p}.$$

In the decoding process, the E's are recalculated with the received symbols, and their ensemble forms a number on the base p which determines univocally the mistransmitted symbol and its correction.

In passing from n to $n+1$, the matrix with n rows and $p^n-1/p-1$ columns formed with the coefficients of the X's and Y's in the expression above is repeated p times horizontally, while an $(n+1)$ st row added, consisting of $p^n-1/p-1$ zeroes, followed by as many one's etc. up to $p-1$; an added column of n zeroes with a one for the lowest term completes the new matrix for $n+1$.

If we except the trivial case of blocks of $2S+1$ binary symbols, of which any group comprising up to S symbols can be received in error which equal probability, it does not appear that a search for lossless coding schemes, in which the number of errors is limited but larger than one, can be systematized so as to yield a family of solutions. A necessary but not sufficient condition for the existence of such a lossless coding scheme in the binary system is the existence of three or more first numbers of a line of Pascal's triangle which add up to an exact power of 2. A limited search has revealed two such cases; namely, that of the first three numbers of the 90th line, which add up to 2^{12} and that of the first four numbers of the 23rd line, which add up to 2^{11}. The first case does not correspond to a lossless coding scheme, for, were such a scheme to exist, we could designate by r the number of E_m ensembles corresponding to one error and having an odd number of 1's and by $90-r$ the remaining (even) ensembles. The odd ensembles corresponding to two transmission errors could be formed by re-entering term by term all the conbinations of one even and one odd ensemble corresponding each to one error, and would number $r(90-r)$. We should have $r+r(90-r)=2^{11}$, which is impossible for integral values of r.

On the other side, the second case can be coded so as to yield 12 sure symbols, and the a_{mk} matrix of this case is given in Table I. A second matrix is also given, which is that of the only other lossless coding scheme encountered (in addition to the general class mentioned above) in which blocks of eleven ternary symbols are transmitted with no more than 2 errors, and out of which six sure symbols can be obtained.

It must be mentioned that the use of the ternary coding scheme just mentioned will always result in a power loss, whereas the coding scheme for 23 binary symbols and a maximum of three transmission errors yields a power saving of $1\frac{1}{2}$ db for vanishing probabilities of errors. The saving realized with the coding scheme for blocks of 2^n-1 binary symbols approaches 3 db for increasing n's and decreasing probabilities of error, but a loss is always encountered when $n=3$.

MARCEL J. E. GOLAY
Signal Corps Engineering Laboratories
Fort Monmouth, N. J

TABLE I

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}
X_1	1	0	0	1	1	1	0	0	0	1	1	1
X_2	1	0	1	0	1	1	0	1	1	0	0	1
X_3	1	0	1	1	0	1	1	0	1	0	1	0
X_4	1	0	1	1	1	0	1	1	0	1	0	0
X_5	1	1	0	0	1	1	1	0	1	1	0	0
X_6	1	1	0	1	0	1	1	1	0	0	0	1
X_7	1	1	0	1	1	0	0	1	1	0	1	0
X_8	1	1	1	0	0	1	0	1	0	1	1	0
X_9	1	1	1	0	1	0	1	0	0	0	1	1
X_{10}	1	1	1	1	0	0	0	0	1	1	0	1
X_{11}	0	1	1	1	1	1	1	1	1	1	1	1

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
X_1	1	1	1	2	2	0
X_2	1	1	2	1	0	2
X_3	1	2	1	0	1	2
X_4	1	2	0	1	2	1
X_5	1	0	2	2	1	1

* Received by the Institute, February 23, 1949.

[1] C. E. Shannon, "A mathematical theory of communication," *Bell Sys. Tech. Jour.*, vol. 27, p. 418; July, 1948.

Contributors to Proceedings of the I.R.E.

J. T. Bolljahn (A'43) was born in Oakland, Calif., on June 10, 1918. He received the B.S. degree in electrical engineering from the University of California in 1941. From August, 1941, until January, 1946, he was employed by the Naval Research Laboratory in Washington, D. C. His work in this position was concerned primarily with the development of aircraft antennas.

J. T. Bolljahn

Since February, 1946, he has been a part-time graduate student and a member of the research staff of the Antenna Laboratory at the University of California.

James G. Buck was born in 1918 in Torrington, Conn. He received the A.B. degree from Dartmouth College in 1940, and the Ph.D. degree from MIT in 1942. During the academic year 1940–1941, he was a fellow of the Cramer Foundation. From 1942 until 1946 he was a member of the staff at the Massachusetts Institute of Technology Radiation Laboratory. During part of 1944 and 1945, while on leave of absence from the Radiation Laboratories, he worked on the Manhattan project for the Westinghouse Electric Company.

James G. Buck

In 1946, Professor Buck was appointed assistant professor of physics at the University of Notre Dame. He is a member of the American Physical Society, the Instrument Society of America, the American Association for the Advancement of Science, Phi Beta Kappa, and Sigma Xi.

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For a photograph and biography of Edward L. Ginzton, see page 1002 of the August, 1948, issue of the Proceedings of the I.R.E.

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For a photograph and biography of J. R. Pierce see page 1003 of the August, 1948, issue of the Proceedings of the I.R.E.

Contributors to Proceedings of the I.R.E.

Herbert J. Carlin (M'47) was born in New York, N. Y., in 1917. He attended Columbia University, receiving the B.S. degree in 1938, and the M.S. degree in 1940. In 1947 he was awarded the D.E.E. degree from the Polytechnic Institute of Brooklyn.

H. J. Carlin

From 1940 to 1945 Dr. Carlin was associated with the Westinghouse Company as a design engineer in the power-system relay section of the meter division, and has written several papers on power-system protection. He joined the Microwave Research Institute of the Polytechnic Institute of Brooklyn in 1945, and has made contributions in the field of microwave networks and microwave power measurements. He holds the position of research supervisor, and lectures in the Graduate School at the Institute.

Dr. Carlin is a member of the American Physical Society, the American Institute of Electrical Engineers, Tau Beta Pi, and Sigma Xi.

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Marvin Chodorow (A'43–SM'47) was born on July 16, 1913, in Buffalo, N. Y. He received the B.A. degree in physics from the University of Buffalo in 1934, and the Ph.D. degree from the Massachusetts Institute of Technology in 1939. During 1940, he was a research associate at Pennsylvania State College. Dr. Chodorow was an instructor of physics at the College of the City of New York from 1941 to 1943, when he became associated with the Sperry Gyroscope Company as a senior project engineer. He remained at Sperry until 1947, when he joined the physics department of Stanford University, as an assistant professor.

Marivn Chodorow

Dr. Chodorow is a member of the American Physical Society, and of Sigma Xi.

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Seymour B. Cohn (S'41–A'44–M'46) was born at Stamford, Conn., on October 21, 1920. He received the B.E. degree in electrical engineering from Yale University in 1942. He received the M.S. degree in communication engineering in 1946, and the Ph.D. degree in engineering sciences and applied physics in February, 1948, from Harvard University.

Seymour B. Cohn

From 1942 through 1945, Dr. Cohn was employed as a special research associate by the Radio Research Laboratory of Harvard University. During part of this time, he represented that Laboratory as a Technical Observer with the United States Army Air Force in the Mediterranean Theater of Operations.

Since March, 1948, Dr. Cohn has been employed by the Sperry Gyroscope Company as a project engineer in the microwave department. He is a member of Tau Beta Pi and an associate member of Sigma Xi. He is now serving on the Papers Review Committee of the IRE.

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E. A. Coomes (M'46–SM'46) was born in Louisville, Ky., on June 27, 1909. He received the B.S. in electrical engineering from the University of Notre Dame in 1931, and M.S. degree in 1933. In 1937 he was awarded the Sc.D. degree in applied physics from the Massachusetts Institute of Technology. From 1933 to 1935, and from 1937 to 1942, he was a member of the teaching and research staffs of the physics department at the University of Notre Dame.

E.A. Coomes

In 1942, Dr. Coomes was granted leave of absence to join the staff of Radiation Laboratory to carry out research on oxide cathodes for microwave magnetrons. He returned to Notre Dame as professor of physics and senior member of the Physical Electronics Group in 1945. He is a Fellow of the American Physical Society.

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Edwin Istvánffy was born in Parkany, Hungary, on January 4, 1895. He received the M.Sc. degree in 1922 from the Technical University of Budapest. Since 1923, he has been with the United Incandescent Lamp and Electrical Co. Ltd., Ujpest, Hungary. In 1928 when the Standard Electric Co. Ltd., Budapest, an International Telephone and Telegraph associate, was established, he joined this company, becoming the technical director in 1938. Most of his work is connected with radio development.

Edwin Istvánffy

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For a photograph and biography of T. G. Mihran, see page 1135 of the September, 1948, issue of the Proceedings of the I.R.E.

John F. Kane was born on January 18, 1922, in Brewer, Maine. He received the B.S. degree in engineering physics from the University of Maine in December, 1943. Following his graduation, he joined the Sperry Gyroscope Company as an assistant project engineer on the microwave development staff, where he remained until April, 1946. Since that time, Mr. Kane has been a candidate for the Ph.D. degree in physics at Stanford University, California, where he holds a teaching and research fellowship.

John F. Kane

Mr. Kane is a member of the American Physical Society, and an associate member of Sigma Xi.

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Laurence A. Manning (S'43–A'45) was born in Palo Alto, Calif., on April 28, 1923. He received the A.B. and M.S. degrees in electrical engineering from Stanford University in 1944 and 1947, respectively. From 1944 to 1945 Mr. Manning was engaged in broad-band microwave oscillator development at the Radio Research Laboratory, Harvard University. Returning to Stanford after the war, he served successively as a teaching assistant in physics, research associate in electrical engineering, and, since 1947, as an acting assistant professor in electrical engineering. He is currently engaged in a study of the effect of meteors upon the upper atmosphere.

L. A. Manning

Mr. Manning is a member of Sigma Xi, Phi Beta Kappa, and of Commission 3, the USA National Committee of the URSI.

❖

Allen S. Meier was born on March 9, 1911, at Windsor, Conn. He received the B.S. degree in physics and mathematics in 1932, and the M.S. degree in physics in 1933 from Trinity College, Hartford, Conn. He was associated with the Pratt and Whitney Machine Tool Co. and the Connecticut Mutual Life Insurance Co. before service in the Army in 1940. After serving with the 704th Military Police Battalion and the 242nd Coast Artillery Corps, he was transferred to the Signal Corps in 1942, and was assigned to the Radiation Laboratory

Allen S. Meier

Contributors to Proceedings of the I.R.E.

of the Massachusetts Institute of Technology, where he was engaged in research and development.

From 1942 to 1946, he served as branch officer of the Antenna Branch, Special Projects Laboratory, Aircraft Radio Laboratories, at Wright Field, Ohio. Following release from the Army, he was employed as project engineer at the Antenna Laboratory, Ohio State University Research Foundation. During 1947, he was associated with the Kinsey Electric Products Corp., Fairburn, Ga., as secretary of the company, and has recently been engaged as a development engineer at Sargent and Co., New Haven, Conn.

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B. Y. Mills was born at Sydney, Australia, in 1920. He received the B.Sc. degree in 1940, and the B.E. degree in 1942, both from Sydney University. He immediately joined the staff of the Radiophysics Division of the Council for Scientific and Industrial Research, and until 1946 was engaged in research and development work in the radar field, particularly in regard to receiver and indicator systems. During the next two years he was interested in the application of radar techniques to linear accelerators, and was successful in developing a million-volt X-ray tube of this type. He has recently begun work in the field of radio astronomy.

B. Y. Mills

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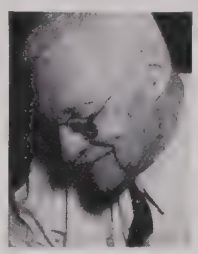
Morton Nadler (A'45) was born in Brooklyn, N. Y., in 1921. He received the bachelor's degree from the College of the City of New York, and undertook subsequent graduate work at the University of Southern California and the Illinois Institute of Technology. During the war he was employed in various electronic instrument research programs under the office of Scientific Research and Development, at the University of Southern California. In the postwar period he worked in television research, first at Belmont Radio Corporation, and then as chief of television receiver design at Sonora Radio and Television Corporation.

Morton Nadler

At present Mr. Nadler is a member of the research staff of Tesla, the national electrical enterprise of the Czechoslovak Republic, in Prague, as director of the electronic applications section.

Greenleaf W. Pickard (M'12–F'15) was born on February 14, 1877, in Portland, Me. He has been associated with radio since 1901, when he became engineer for the American Wireless Telegraph and Telephone Company. In 1902, he was made chief engineer for the Federal Wireless Telegraph and Telephone Company. Later, he joined the American Telephone and Telegraph Company, remaining until 1907, when he organized the Wireless Specialty Apparatus Company, which became the R.C.A. Victor Company of Massachusetts. From 1942 to 1945 Mr. Pickard was director of research for the American Jewels Corporation. He is now associated with the Cosmic Terrestrial Research Laboratory, Massachusetts Institute of Technology, and with the firm of Pickard and Burns, consulting engineers.



G. W. Pickard

Mr. Pickard received the IRE Medal of Honor in 1926 for his "contributions as to crystal detectors, coil antennas, wave propagation and atmospheric disturbances." He also was the recipient of the Armstrong Medal of the Radio Club of America in 1940. He has served on numerous IRE committees, including the Board of Editors, Constitution and Laws, Wavelength Regulation, and Wave Propagation, and was actively associated with the organization of the Boston Section, in 1914. Mr. Pickard was a member of both the Wireless Institute and the Society of Wireless Telegraph Engineers, when these two organizations fused into the present IRE on May 13, 1912. He was President of the IRE in 1913.

Mr. Pickard is a Fellow of the American Academy of Arts and Sciences, as well as of the American Institute of Electrical Engineers and the Radio Club of America. He also holds membership in the American Geophysical Union, the American Meteorological Society, and is a life member of the *Société des Radoélectriciens*.

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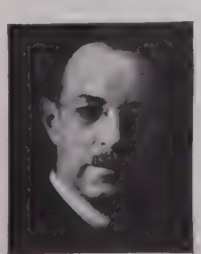
Harlan T. Stetson (A'31) was born in Haverhill, Mass., on June 28, 1885. After graduating from Brown University, he received the Sc.M. degree from Dartmouth College in 1910, and the Ph.D. degree from the University of Chicago in 1915. He was associated with the physics department at Dartmouth for four years, and later taught astronomy and mathematics at Northwestern University. From 1916 to 1929, while he was an assistant professor of astronomy at Harvard University, Dr. Stetson became associated with Mr. Pickard in the investigation of the effect of sunspots on radio reception. From 1929 to 1934 Dr. Stetson was Perkins professor of astronomy at Ohio Wesleyan University and director of the Perkins Observatory, as well as lecturer at Ohio State University. He returned to Harvard in 1934 as a research associate in geophysics. He joined the Massachusetts Institute of Technology in 1936, and is now the director of the Cosmic Terrestrial Research Laboratory at Needham, Mass.



H. T. Stetson

Dr. Stetson is the author of numerous papers on solar activity, radio reception, and ionization of the upper atmosphere. He has been chairman of the Special Committee on Cosmic Terrestrial Relationships of the American Geophysical Union, National Research Council, since 1938. He is the author of "Man and the Stars," "Earth, Radio and the Stars," "Sunspots and Their Effects," and "Sunspots in Action."

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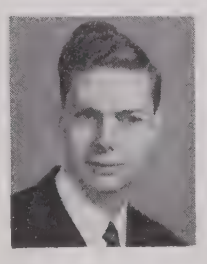
Willard P. Summers (S'45–A'47) was born on August 7, 1922, at Bellevue, Ohio. He attended Findlay College, received the B.E.E. degree from Ohio State University in June, 1946, and did graduate work in antenna theory from 1947 to 1948.



Willard P. Summers

From 1944 to 1945, Mr. Summers was an engineer at WOSU. He was a research associate at the Antenna Laboratory, Ohio State University, from June, 1946, to August, 1948.

At present, Mr. Summers is in charge of instrumentation for the Aeronautical Research Laboratory, Ohio State University. He is a member of Eta Kappa Nu and Sigma Pi Sigma.

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Nelson Wax was born on April 2, 1917, at Philadelphia, Pa. He received the B.S. degree in 1937 and the M.S. degree in 1938, from the Moore School of Electrical Engineering, University of Pennsylvania, and the Ph.D. degree in 1942 from the Ohio State University. Dr. Wax was with the Bell Telephone Laboratories, Inc., from 1942 to 1948. Since February, 1948, he has been an assistant professor of electrical engineering at the University of Illinois.

Nelson Wax

Institute News and Radio Notes

Technical Committee Notes

The **Standards Committee** held an annual meeting on March 8, 1949. The new chairman is J. G. Brainerd of the University of Pennsylvania; A. G. Jensen of BTL and L. G. Cumming of IRE Headquarters are vice-chairmen. Standards on *Radio Aids to Navigation: Definitions of Terms, 1949;* and *Railroad and Vehicular Communications: Methods of Testing, 1949* have been approved by the Committee and will shortly be published. Mr. Jensen reported for the Definitions Co-ordinating Subcommittee, which has two purposes: to save work and time for groups writing definitions by calling attention to any overlapping in work, and to establish a more efficient transfer of information between the IRE and other organizations. It is hoped that the Subcommittee will receive definitions while they are in a tentative stage, so that they may be referred to ASA C-42 Committee for agreement prior to adoption by the IRE. The **IRE/AIEE Co-ordinating Committee on Definitions** has agreed to set up a group to work on the term "Noise." It is advisable that no other committee work on this subject until the group's task is completed. The meeting was addressed by the Institute's Standards Co-ordinator, W. R. G. Baker, who offered the IRE's thanks to A. B. Chamberlain for his fine work as Chairman of the Standards Committee, and also thanked the chairmen of all the technical committees for their accomplishments during the year. He spoke of a new method of reproducing Standards by photo-offset, which will require strict adherence to the rules governing preparation of drafts of standards. . . . A meeting of the **Antennas and Wave Guides Committee** was held on March 30 in Washington, D. C., and L. C. Van Atta was chosen chairman for the coming year. A vote of thanks was given to the retiring chairman, P. S. Carter. . . . J. G. Brainerd, retiring chairman of the **Circuits Committee,** introduced the new chairman, W. N. Tuttle, at the March 9 meeting. The Committee is continuing its work on definitions, and subcommittees will be formed for this activity. . . . L. R. Nergaard will assume the duties of chairman of the **Committee on Electron Tubes** and Solid State Devices, it was announced on March 7. The Committee plans to have a standard on definitions of terms ready for publication shortly. . . . At the meeting of the **Receivers Committee** on March 10, R. F. Shea was introduced as the new chairman. W. O. Swinyard is the retiring chairman. . . . The **Research Committee** held a meeting on March 9, during which D. E. Chambers led the Committee in a discussion of its scope. The Committee agreed to secure for publication interpretative or review papers and original papers, to promote a "Letters to the Editor" page in the Proceedings, to prepare abstracts, and to report on technical meetings. . . . The **Video Techniques Committee,** under the chairmanship of J. E. Keister, met on March 9. Three new subcommittees have been formed: Definitions, headed by R. H. Daugherty, Jr.; Methods of Measurement and Test for Video Systems and Components, headed by W. J. Poch; and Methods of Measurement and Test for Video Signal Transmission, headed by L. W. Morrison. Besides the material which these new subcommittees are preparing for standardization, the Subcommittee on Methods of Measurement and Test for Utilization, Including Video Recording, under the chairmanship of Vernon J. Duke, is preparing six tutorial reports for publication. . . . At the meeting of the **Wave Propagation Committee** on March 9, it was announced that C. R. Burrows would head the Committee for the coming term. The Committee reviewed the *Glossary of Terms Used in Radio Propagation,* which had been circulated for comment by the British Standards Institute. It also discussed its activities in connection with the JTAC. . . . The **Committee on Professional Groups** met on March 7. The chairman W. L. Everitt, announced that three Groups have been formally organized and approved: Audio, Broadcast Engineers, and Antennas and Wave Propagation. Six others are under consideration: Circuit Theory, Nuclear Science, Vehicular and Railroad Radio Communications, Receivers, Transmitters, and Electron Tubes. The Committee shall have primary jurisdiction on policy, which will include the actual approval of Groups and their objectives. Operation of groups will be under the control of the Executive Committee through the Standards Co-ordinator. Minor revisions of the Professional Groups Manual were authorized, and a plan was adopted for stimulating action in the Sections for forming Section Groups, the Committee acting as a clearing house for the Sections in supplying information, speakers, papers, etc. It was decided that all members of Professional Groups, national or sectional, must be members of the Institute. All Groups shall hold one technical conference of national scope each year.

Calendar of COMING EVENTS

Central Section Regional Meeting, Society of Motion Picture Engineers, Toledo, Ohio, June 10

IRE Conference on Electronic Devices, Princeton, N. J., June 20 and 21

AIEE Summer General Meeting, Swampscott, Mass., June 20–24

NBS Symposium on Construction and Applications of Conformal Maps, Los Angeles, Calif., June 24–25.

NBS Symposium on Probability Methods in Numerical Analysis. Los Angeles, Calif., June 27–29.

AIEE Pacific General Meeting, San Francisco, Calif., August 23–26

1949 IRE West Coast Convention, San Francisco, Calif., August 30–September 2

1949 National Electronics Conference, Chicago, Ill., September 26–28

National Radio Exhibition, Olympia, London, England, September 28 to October 28

AIEE Midwest General Meeting, Cincinnati, Ohio, October 17–21

1950 IRE National Convention, New York, N.Y., March 6–9

Military Standards Agency Reorganized

Under the terms of a charter signed by the assistant secretaries of the three military services, the government body organized in December, 1943, as the Army-Navy Electronic Standards Agency has been reconstituted as the Armed Services Electro Standards Agency. The change provides for official participation by the Air Force, which became a separate component of the National Military Establishment under the provisions of the National Security Act of 1947.

The purpose of the Standards Agency is to reduce the number of styles and types of electronic components used in the manufacture of military equipment of all kinds, to insure their quality and dependability, and to designate approved sources of supply.

British "Radiolympia" Exhibit to be Held in Fall

Television, as perfect technically as it can be demonstrated in all stages from studio to receiver, will be a feature of the sixteenth National Radio Exhibition ("Radiolympia") to be held at Olympia, London, England, from September 28 to October 8.

Other displays will include an enlarged section for communications equipment, navigational aids, and electronics in industry, and exhibits for the first time since the war by the Royal Navy, the Army, and the Royal Air Force. The Ministry of Supply, the Department of Scientific and Industrial Research, and the GPO will also exhibit.

Constitutional Amendment Ballot

In accordance with Article IX, Section 2 of the Institute Constitution, the ballots on amending Article II, Section 1(c) and Article II, Section 2(c) of the IRE Constitution were counted on May 3, 1949, under the supervision of the Tellers Committee, J. L. Callahan, Acting Chairman. The final result of the ballot count is as follows:

	Yes	*No*	*Total*
Total	812	2334	3146
Per cent	25.8	74.2	100

Total ballots mailed..... 7,015
Total ballots received..... 3,189
—45.4 per cent of ballots mailed
Total ballots void..... 43
— 0.6 per cent of ballots mailed
Total ballots counted..... 3,146
—44.8 per cent of ballots mailed

Report of the Secretary—1948

To the Board of Directors,
The Institute of Radio Engineers

Gentlemen:

The Secretary again submits a report, required annually as stipulated in the By-laws, of the status of Institute affairs resulting from activities during 1948.

It is especially gratifying to note that Institute growth continues unabated both in membership and activities. Membership is spread over 63 countries. Student Branches have increased over 100 per cent from 27 to 59. Sections increased from 43 to 48 or about 11 per cent. Additional data and the usual charts are included herewith. (Figs. 1–4).

The past year has seen the inauguration of the Regional Director plan, with a reduced number of Board of Directors meetings. The attendance at these was excellent, and not only were regional problems more fully dealt with, but members of the various Sections enjoyed a closer relationship with the Institute through their ability to express views through the Regional Directors. These Directors carry to their Regions authentic information resulting from their participation in the operations of the Board. A plan was adopted to render limited financial assistance for the handling of approved Regional meetings, which should go far in promoting activities in these several far-flung areas that have area interests.

Further encouragement toward better Section activities was provided through the increase in Section membership rebates, which took effect at the first of the year.

The year 1948 saw the commencement of a new conception created by the Board, the Professional Group system. This plan was evolved in an effort to develop a method whereby members having common interests in a given specialized field can give expression to those special interests and develop related activities. The rapid growth of the general field of radio and electronics and of this Institute dictated the need for something of this kind. The response seems to justify the plan, three Professional Groups having been organized; and it appears that the needs of these particular highly specialized fields will be fulfilled thereby.

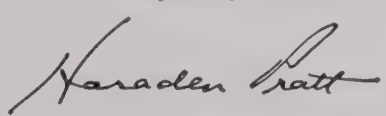
Convention and meeting activities provide another gauge of growth. A total of 14,459 persons attended the 1948 National Convention, where 128 technical papers were presented during the 29 technical sessions, and 180 exhibits were shown. Attendance included persons from 31 foreign countries. This attendance was 21 per cent greater than that at the 1947 National Convention. Mention is made of other important meetings, including the West Coast IRE Convention, the New England Radio Engineering Meeting, the Southwestern IRE Conference, the National Electronics Conference, the Rochester Fall Meeting, the URSI Meeting at Washington, and the Canadian IRE Convention.

Technical committee activities have greatly increased during 1948, as will be seen later in this report.

Early during the year the Radio Technical Planning Board went out of existence, as its form of organization no longer served the problems of the day. In its place, the Institute, in concert with the RMA and with the encouragement of the FCC, created, on June 20, an eight-member organization called the "Joint Technical Advisory Committee." These eight persons are jointly selected by the Boards of Directors of IRE and RMA, and serve for two-year terms. The Committee has been very active, has issued technical reports on questions of public interest upon which the FCC has sought information, and has presented technical testimony at meetings held under FCC auspices. It is hoped that through this Committee a real public service will continue to be provided.

The Institute, by very careful management, met its budget, as can be noted from the accompanying statement. However, the Institute's income is inadequate to provide many desired services, to publish more of the available technical papers in the Proceedings, and to increase the surplus, which is not keeping pace with Institute growth. The advent of 1949 finds the Institute management with a better understanding of its problems, and it is hoped that the new activities introduced during 1948 will render real service to the membership.

Respectfully submitted,



Haraden Pratt, *Secretary*

March 24, 1949

Table I—Membership Distribution by Grades

Grade	*As of Dec. 31, 1948* *Number*	*% of Total*	*As of Dec. 31, 1947* *Number*	*% of Total*	*As of Dec. 31, 1946* *Number*	*% of Total*
Fellow	259	1.1	239	1.1	218	1.2
Senior Member	2,192	9.4	2,068	9.8	1,763	9.7
Member	3,334	14.2	3,017	14.4	2,330	12.8
Associate	11,713***	50.0	12,079**	57.4	11,591*	63.9
Student	5,939	25.3	3,634	17.3	2,252	12.4
Totals	23,437		21,037		18,154	

* Includes 1,701 Voting Associates.
** Includes 1,490 Voting Associates.
*** Includes 1,260 Voting Associates.

Table II—Five-Year Analysis of U. S. and Foreign Membership

	1948	*1947*	*1946*	*1945*	*1944*
Total	23,437	21,037	18,154	15,779	13,137
U.S. and Possessions	21,048	18,723	15,898	14,053	11,596
Foreign (including Canada)	2,389	2,314	2,256	1,726	1,541
Per Cent Foreign	10.2	11.0	12.4	10.9	11.7

Membership

At the end of the year 1948, the membership of the Institute, including all grades, was 23,437, an increase of 2,400, or 11 per cent over the previous year. The 2,400 member increase in 1948 compares favorably with 2,375 and 2,883, the increases for 1946 and 1947, respectively. The percentage increase was 16 per cent in 1946, and 15 per cent in 1947. The membership trend from 1912 to date is shown graphically in Fig. 2.

The distribution of members in the various grades for the years 1945, 1946, 1947, and 1948 is shown in Fig. 3. Actual figures for 1946, 1947, and 1948 are shown in Table I. Note that the loss of Associates was due largely to the loss of Voting Associates because of transfer to Member grade. Of the 10,453 nonvoting Associates, 2,680 have been in that grade for more than five years. The membership ratio of Associates to Higher Grades was 6 to 1 in 1944, 4 to 1 in 1945, less than 3 to 1 in 1946, and about 2 to 1 in 1947 and 1948, a very satisfactory trend. Note also that the drop in percentage of higher grade members was due to the very substantial increase of Student members.

Table II shows an analysis for the past five years of the distribution of members at home and abroad. It may be noted that the foreign membership increased rapidly at the end of the war. Monetary exchange difficulties since the end of the war have contributed to the reduced increase in foreign membership during the past two years.

It is with deep regret that this office records the death of the following members of the Institute during the year 1948:

Fellows

Louis Cohen (F'15)
Harry Diamond (A'26–M'30–F'43)
Kenneth B. Warner (A'18–M'22–F'36)
William Wilson (M'26–F'28)

Senior Members

Kenneth N. Cumming (A'16–M'28–SM'43)
David M. Davis (M'43–SM'43)
Cecil E. Haller (A'34–M'40–SM'43)
Ralph G. McCurdy (M'42–SM'43)
Frank Rieber (M'41–SM'43)
George H. Rockwood, Jr. (A'31–SM'46)
McMurdo Silver (SM'43)
Frank N. Waterman (A'12–M'15–SM'43)

Members

Howard C. Dunn (A'43–M'46)
Philip J. Konkle (A'28–M'44)
William W. Robertson, Jr. (A'37–M'46)
Richard R. Syrdal (M'46)

Associates

Robert L. Anderson (S'40–A'41)
Richard B. Arnson (A'44)
Ralph S. Clarke (A'21–VA'39)
R. Douglas Clerk (A'37–VA'39)
David L. Curtis (A'44)
George B. David (A'43)
Frank H. Fay (A'38–VA'39)
Edwin W. Hamlin (A'40)
Alexander M. Haubrich (A'37–VA'39)

(Continued on page 663)

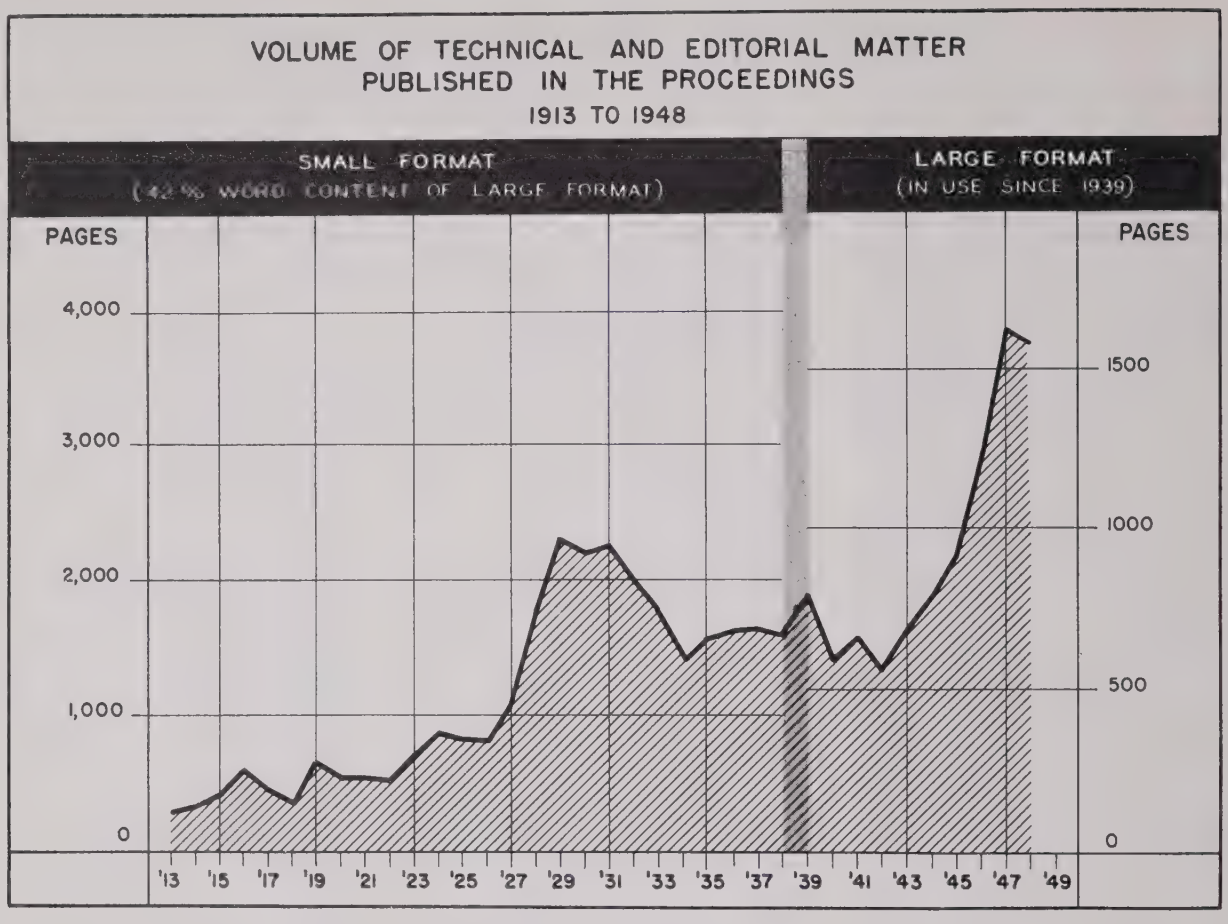

VOLUME OF TECHNICAL AND EDITORIAL MATTER
PUBLISHED IN THE PROCEEDINGS
1913 TO 1948
SMALL FORMAT
(42% WORD CONTENT OF LARGE FORMAT)
LARGE FORMAT
(IN USE SINCE 1939)
PAGES
4,000
3,000
2,000
1,000
0
PAGES
1500
1000
500
0
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49

Fig. 1

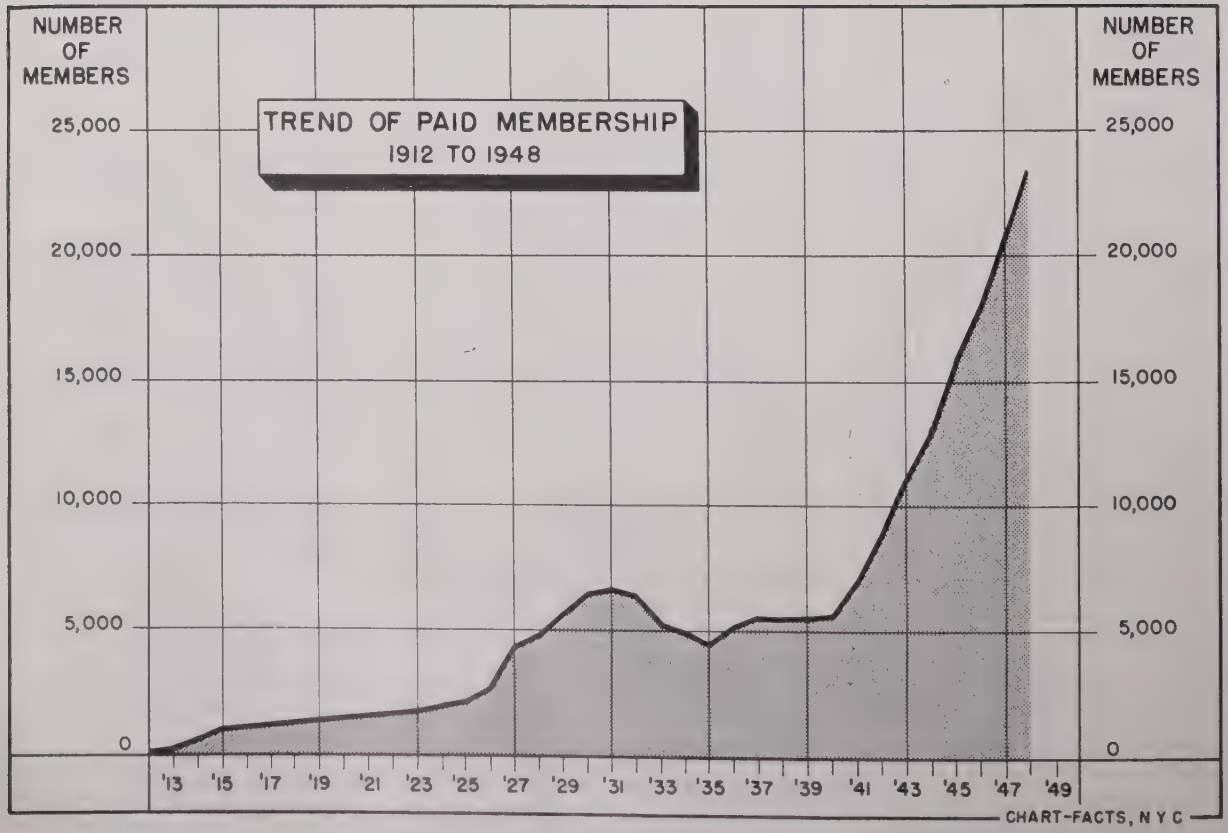

NUMBER OF MEMBERS
TREND OF PAID MEMBERSHIP
1912 TO 1948
NUMBER OF MEMBERS
25,000
20,000
15,000
10,000
5,000
0
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49
CHART-FACTS, N Y C

Fig. 2

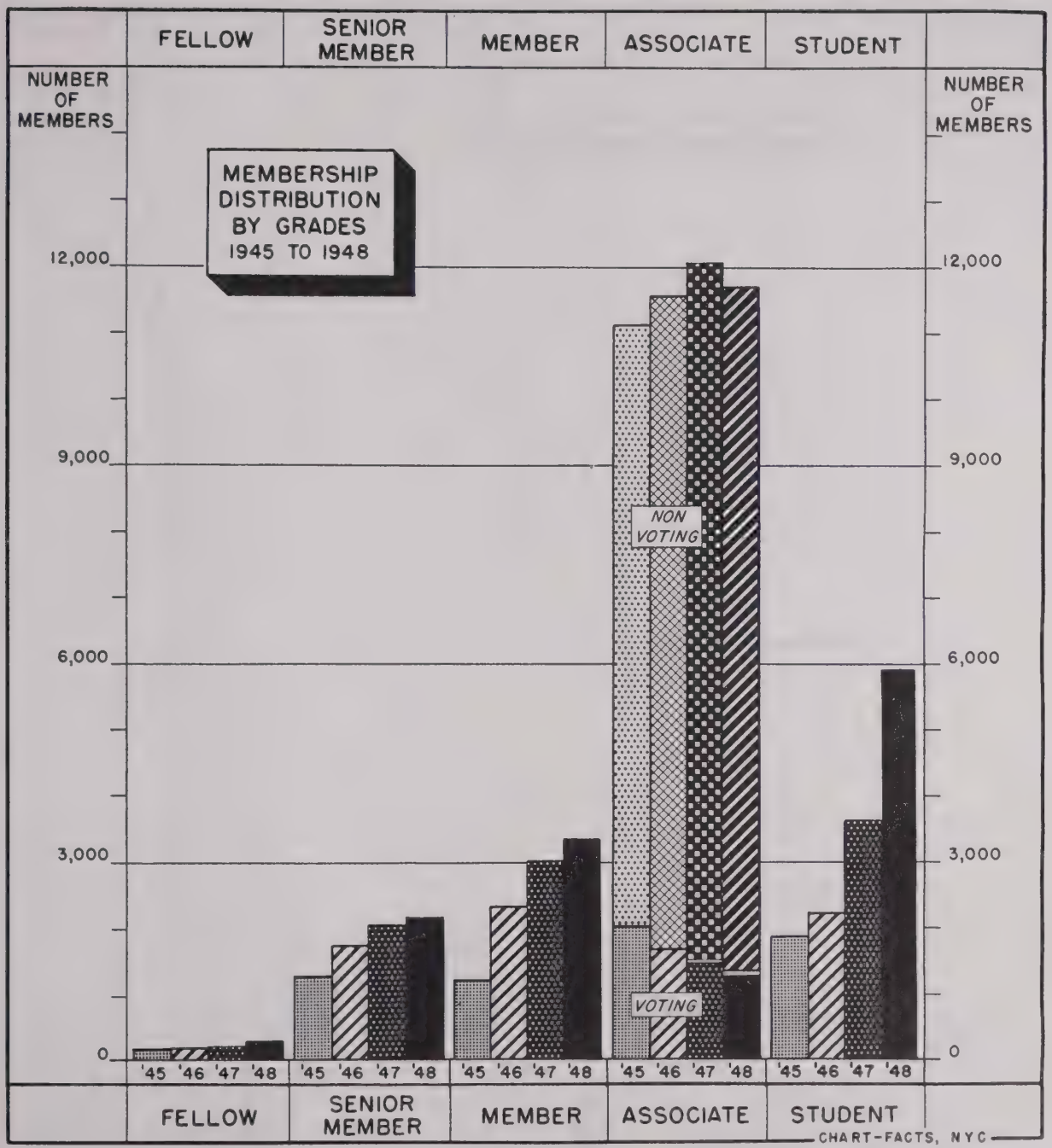


Fig. 3

(*continued from page 661*)

Frank R. Hillyer (A'45)
Albert E. Johnson (A'46)
Charles J. Lemieux (A'38–VA'39)
Virgil L. Miller (A'48)
Alfred J. Mills (A'44)
Howard R. Molton (A'45)
Irvin Nevins (A'45)
Willis B. Plummer (S'36–A'40)
George E. Rueppel (A'43)
Jack M. Sadowsky (A'37–VA'39)
Kenneth L. Scott (A'21–VA'39)
William J. Sharpe (A'44)
Monroe H. Sheppard (S'43–A'45)
Allen C. Stecher (A'44)
Llewelyn L. B. Summers (A'40)
Charles W. Taussig (A'22–VA'39)
Mervin J. Ullman (A'46)
William J. Yahnke (A'46)

Editorial Department

The year 1948 again found the Editorial Department faced, on the one hand, with an ever-increasing inflow of submitted papers, and on the other with rigid space limitations imposed by stern budgetary realities. The problem, while it could not be said to have been solved as of the end of the year, was being brought under partial control by drastic editorial selection and compression.

In 1948 there were published in the PROCEEDINGS a total of 2,452 pages, including covers. Of these, 1,592 were editorial pages and 860 advertising pages. Of the editorial pages, 1,151⅓ were devoted to technical papers, (including discussions and correspondence), 166⅔ to Abstracts and References, and 274 to nontechnical material (including covers, contents pages, and annual index). Of the advertising pages, 757⅓ represented paid advertising, while the remaining contained useful editorial filler in the form of Institute Membership and Section-meeting lists, and news of new products and the industry in general.

The total of 2,452 pages published during the year compares with 2,576 in 1947 and 2,240 in 1946. The number of editorial pages (1,592) compares with 1,636 in 1947, and 1,256 in 1946. Advertising pages numbered 940 in 1947 and 984 in 1946. The number of editorial pages published each year since 1913 is shown in Fig. 1.

Technical papers totaling 173 were published in 1948, as against 172 in 1947. Authorship of these papers was by 241 individuals, of whom 176, or 73 per cent, were

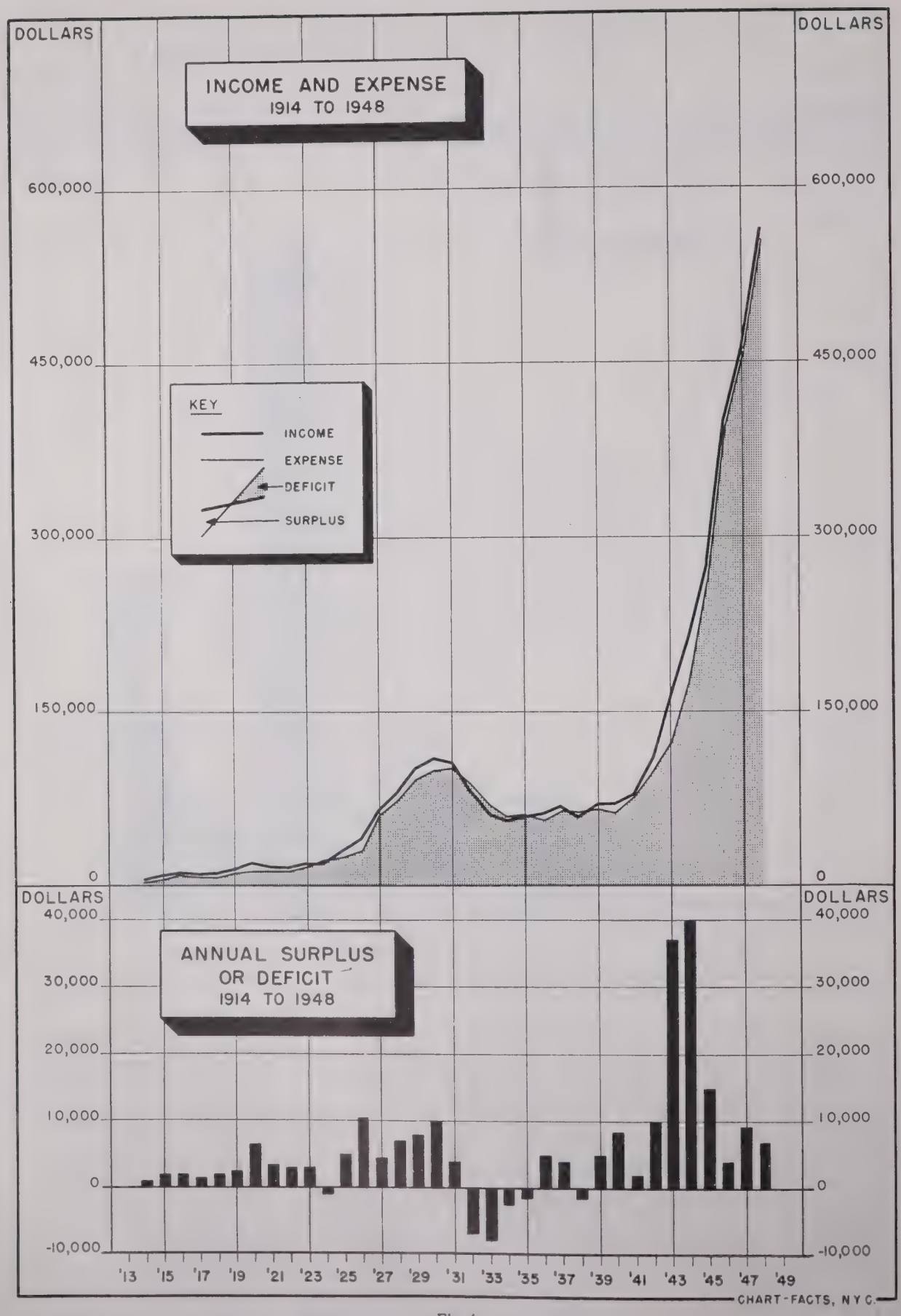

DOLLARS
INCOME AND EXPENSE
1914 TO 1948
600,000
450,000
300,000
150,000
0
KEY
INCOME
EXPENSE
DEFICIT
SURPLUS
DOLLARS
ANNUAL SURPLUS
OR DEFICIT
1914 TO 1948
40,000
30,000
20,000
10,000
0
-10,000
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49
CHART-FACTS, N.Y.C.

Fig. 4

members of the Institute. In 1947, 205 of the 266 authors, or 77 per cent, were members.

The backlog of papers on hand in the Editorial Department at the end of 1948 included 141 papers, totaling an estimated 981 PROCEEDINGS pages, of which 69 papers representing 442 pages had been accepted, the remainder being under review. At the start of the year the backlog was only 95 papers with 651 pages, having been reduced from the postwar peak of 171 papers totaling 1,225 pages by the "expanded publication program" executed during the last part of 1947. Under this program the size of issues was increased from an average for the first eight issues of 1947 of 109 pages of editorial content to 144 pages in September, 1947, 176 pages in October, 224 pages in November and December, respectively, and concluding with 176 pages in the January, 1948 issue. The average number of pages for the remaining issues of 1948 was 128 pages, or 19 more than the average for the "regular" issues of 1947.

Despite this increased regular allotment, the volume of material received was so great as to make it impossible to hold entirely the gains on the backlog which had been achieved by the expanded publication program.

The volume of papers submitted for publication continues to increase markedly. During 1947, 201 papers totaling an estimated 1,298 PROCEEDINGS pages were submitted, or an average of 16.7 papers and 108.2 pages per month. During 1948 these receipts increased to 289 papers of 2,043 pages, or 24 papers and 170 pages per month.

To aid in keeping the backlog within manageable dimensions and to enable more effective employment of the editorial budget allocated by the Executive Committee, new procedures were set up within the Editorial Department and in the Editorial Administrative Committee. In consequence, even more stringent standards have been established for the acceptance of papers, and maximum compression feasible is required in all accepted papers.

In connection with the related problems of printing costs and lack of space, studies were made of possible methods of achieving printing production economies. A particularly detailed study was made of the possibilities of space and cost saving by the use of smaller typeface sizes. The study revealed that no significant economies could be realized by such a course without using measures which would result in degradation of legibility and appearance.

With the approval of the Executive Committee, modifications in format and treatment of nontechnical material were made to conserve space for technical papers. This has been accomplished with slight impairment or reduction of content, and even with some improvement in readability and discernability. Publication of the Abstracts and References Section of the PROCEEDINGS continued during the year. The question of its merit relative to the great need for additional space for technical papers was given careful consideration, and the membership at large was asked to express opinions. More than 100 responses were received, the opinions being overwhelmingly favorable for its continuance. The Editorial Department was finally instructed by the Executive Committee to continue publication of the section, at least throughout 1949.

An innovation in the printing production procedures of the Institute was the decision to reproduce the editorial section of the 1949 Yearbook by the photo-offset method of reproduction, the membership lists being composed by the varitype method. It is expected that appreciable economies will be effected by the use of these methods, and that production will be considerably expedited, with tolerable impairment of appearance and legibility, which is regarded as of negligible importance because of the nonpermanent, reference nature of the book.

Several Standards reports were produced or were in production during the year, which are listed under the subject of Technical Activities in this report.

The Editorial Department is directed by Editor Alfred N. Goldsmith in matters of editorial policy, content, and format, and by Executive Secretary George W. Bailey in matters of administration, both functioning through Technical Editor Clinton B. DeSoto. An effective staff assists these officers. It has been greatly aided by the helpful advice and assistance unstintingly given by the 78 members of the Board of Editors, the 92 members of the Papers Review Committee, the Papers Procurement Committee, and the Editorial Administrative Committee.

Section Activities

We were glad to welcome five new Sections into the Institute during the past year. They are as follows:

San Antonio	(March)	1948
New Mexico	(April)	1948
Toledo	(April)	1948
Omaha-Lincoln	(Sept.)	1948
Salt Lake	(Oct.)	1948

The total number of Sections is now 48. There has been a substantial increase in membership of these Sections, with a few exceptions. It should be borne in mind that most Sections with noticeable decreases in membership released substantial numbers of members to new Sections. In addition, during the year there has been formed the following group, unofficially designated as a Sub-section:

Center County (Emporium)

Student Branches

The Institute's program with respect to Student Branches, reactivated in 1947, continued to flourish in 1948. The number of Student Branches formed during 1948 was 32, 14 of which operate as joint IRE-AIEE Branches. The total number of Student Branches is now 59, 26 of which operate as Joint IRE-AIEE Branches. This unprecedented increase of student interest was accompanied by a large increase in student members. Additional applications for the establishment of Branches are now in process. This work, under the direction of E. K. Gannett, Assistant Secretary, is very productive in building the foundations upon which future Institute progress will depend.

Following is a list of the Student Branches formed in 1948:

Alabama Polytechnic Institute; *University of Arizona; Polytechnic Institute of Brooklyn; California State Polytechnic College; *Columbia University; University of Dayton; University of Detroit; *University of Florida; Illinois Institute of Technology; *Iowa State College; John Carroll University; Lehigh University; Manhattan College; *University of Maryland; *Massachusetts Institute of Technology; *Michigan State College; *Missouri School of Mines and Metallurgy; Newark College of Engineering; University of New Mexico; *University of North Dakota; *University of Notre Dame; Oregon State College; *Princeton University; *University of South Carolina; South Dakota School of Mines & Technology; St. Louis University; *Agricultural & Mechanical College of Texas; *University of Toledo; Utah State Agricultural College; University of Virginia; University of Wisconsin; and University of Wyoming.

Technical Activities

Technical Committees. During 1948, 20 technical committees, with their subcommittees and task groups, held a total of 112 meetings at Institute Headquarters, 21 meetings at the Hotel Commodore during the National Convention, and 25 meetings in other localities, or a total of 158 meetings, a substantial increase over 1947.

The following standards prepared by the IRE technical committees were published during the year:

- Standards on Abbreviations, Graphical Symbols, Letter Symbols, and Mathematical Signs, 1948
- Standards on Antennas: Methods of Testing, 1948
- Standards on Antennas, Modulation Systems, and Transmitters: Definitions of Terms, 1948
- Standards on Television: Definitions of Terms, 1948
- Standards on Television: Methods of Testing Television Receivers, 1948

In addition, publication of *Standards* on *Radio Receivers: Methods of Testing Frequency-Modulation Broadcast Receivers*, 1947, was completed in January, 1948.

In addition to the standards published, approval of the Board of Directors was secured for *Standards on Receivers: Methods of Testing Amplitude-Modulation Broadcast Receivers.* Approval was also secured for a large portion of the revision to the standards on Definitions of Terms relating to Electron Tubes and to the standards on Methods of Testing Electron Tubes. These standards will be available during 1949. The Standards Committee prepared Proposed Standard Frequency-Band Designations for publication in the PROCEEDINGS. It will be considered for standardization in 1949. The Committee on Electroacoustics, in co-operation with ASA, prepared a glossary of acoustical terms which has been published and distributed as a preliminary ASA standard. It will be adopted as a final standard by IRE and ASA during 1949.

The Technical Committee on Annual Review completed a survey, "Radio Progress During 1948." Thirty-six pages in the March, 1949, issue of PROCEEDINGS are devoted to publication of this material.

* Joint IRE-AIEE Student Branches.

The Nuclear Studies Committee procured a series of papers in its field for publication in the PROCEEDINGS. Four papers have appeared in 1948 issues, and one paper per month is available and scheduled for publication in 1949.

A Definitions Co-ordinating Subcommittee of the Standards Committee was established during the year. Its function has been to correlate definitions of all terms under consideration within the technical committee structure of the IRE and, in addition, to take cognizance of the definitions of outside agencies to eliminate duplication of man hours and conflict. Work was started at Headquarters toward the compilation of a master index of all terms defined by IRE and other organizations having definitions in the electronics field. This index will be made continually available to all IRE committees, and, upon request, to other professional societies.

Two major symposia were sponsored by technical committees during 1948; the Electron Tube Conference, and the Conference on Electronic Instrumentation in Nucleonics and Medicine. The Electron Tube Conference, sponsored by the Committee on Electron Tubes, was held on June 28 and 29 at Cornell University, and was attended by over 200 scientists. The Nucleonics Conference, sponsored by the Nuclear Studies Committee in co-operation with AIEE, was held in New York, N. Y., on November 29 and 30, and December 1. It was attended by 550 scientists. Both conferences are considered to have been outstanding contributions to electronic engineers.

Professional Group System. Two groups, namely the "Audio Group," established in June, and the "Broadcast Engineers Group," established in July, were becoming active by the end of 1948. The formation of Professional Groups in "Nuclear Science" and "Antennas and Wave Propagation" was under way. In addition, interest was developing for the formation of Professional Groups in the fields of Circuit Theory, Railroad and Vehicular Communications, Radio Receivers, Radio Transmitters, Telemetering, and Quality Control.

Joint Technical Advisory Committee. The first task undertaken by the JTAC resulted from a request by the FCC to study the problem of uhf television development and to provide information for the FCC hearing scheduled for September 20. The JTAC provided this information in its Proceedings, Volume 1, entitled "Utilization of Ultra-High Frequencies for Television," Docket 8976, September 20, 1948. This report was followed by a second volume, "Allocation Standards for vhf Television and FM Broadcasting," Docket 9175, December, 1948.

General Joint Technical Activities. During 1948 there was an appreciable increase in the co-operative technical activities of the Institute with other professional societies and federal agencies. Sixty-five committee meetings were held jointly with other organizations during the year, in addition to the 158 meetings of technical committees previously mentioned. Work on this total of 223 committee meetings was accomplished by 580 committee members, of whom approximately 180 were engaged in the joint committee activities. These meetings represent co-ordination of technical activities with the American Standards Association, American Institute of Electrical Engineers, Joint Technical Advisory Committee, Radio Technical Committee on Aeronautics, National Research Council, Army-Navy Electrical and Electronics Standards Agency, and its successor, Armed Services Electro Standards Agency, International Scientific Radio Union, Research and Development Board of the National Military Establishment, Atomic Energy Commission, Civil Aeronautics Administration, and International Civil Aviation Organization.

Technical activities were carried on under the guidance of the Standards Co-ordinator W. R. G. Baker, Technical Secretary L. G. Cumming, and a competent staff.

Fiscal

A condensed summary of income and expenses for 1948 is shown in Table III, and a balance sheet for 1948 is shown in Table IV. Income and expenses for each year since 1914 are shown graphically in Fig. 4.

TABLE III—SUMMARY OF INCOME AND EXPENSES, 1948

Income		
Advertising	$157,501.64	
Member Dues and Conventions	339,177.92	
Subscriptions	33,679.55	
Sales Items, Binders, Emblems, Standards, etc.	18,229.77	
Investments Income	10,337.60	
Miscellaneous Income	3,296.27	
Total Income		$ 562,222.75
Expense		
PROCEEDINGS Editorial Pages	$142,372.35	
Advertising Pages	81,979.41	
Yearbook	31,423.27	
Section Rebates	21,228.76	
Sales Items	20,991.33	
Miscellaneous Printing	4,807.77	
General Operations	157,139.73	
Convention Cost	89,802.44	
Total Expense		$ 549,745.06
Surplus		12,477.69
Reserve for Depreciation		$ 5,880.59
Net Surplus		$ 6,597.10

TABLE IV—BALANCE SHEET—DECEMBER 31, 1948

Assets		
Cash and Accounts Receivable	$211,827.25	
Inventory	12,061.91	
Total Current Assets		$ 223,889.16
Investments at Cost	361,023.50	
Building and Land at cost	356,687.30	
Furniture and Fixtures at cost	67,394.92	
Other Assets	64,661.38	
Total		849,767.10
Total Assets		$1,073,656.26
Liabilities and Surplus		
Accounts Payable	7,371.38	
Federal Taxes on emblems, etc.	1,979.78	
Total Current Liabilities		$ 9,351.16
*Deferred Liabilities		261,635.13
Total Liabilities		$ 270,986.29
Reserve for Depreciation		16,665.72
Surplus—Donated	596,468.83	
Surplus—Earned	189,535.42	
Total Surplus		786,004.25
Total Liabilities and Surplus		$1,073,656.26

* 1949 items, PROCEEDINGS for members and subscribers, Advertising, and Convention service.

Industrial Engineering Notes[1]

NBS Develops Absolute Values

Recent experimental work at the National Bureau of Standards has resulted in developments of importance to the design of cathode-ray tubes and many other electronic devices.

The absolute value of the magnetic moment of the proton has been determined with unprecedented accuracy, and the value of the basic constant e/m—electric charge to mass ratio of the electron—with even greater accuracy.

A complete report on the development was published in the May issue of *The Technical News Bulletin*, monthly publication of the NBS, copies of which may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Lack Succeeds Sarnoff as AFCA President

RMA Director Frederick R. Lack was elected to succeed David Sarnoff as president of the Armed Forces Communications Association, which met in Washington on March 28 and 29. Close co-operation and co-ordination between government and industry in the communications operating and manufacturing fields were emphasized by speakers on both sides during the third annual meeting of the association.

New Export Schedule Published By OIT

A new comprehensive export schedule (No. 27), containing all export regulations in effect on March 31, 1949, was published by the Office of International Trade, U. S. Department of Commerce.

. The new edition supersedes No. 26, published last fall, and covers all changes in regulations previously described in Current Export Bulletins 485 to 517, inclusive. Both the new Comprehensive Export Schedule and all Current Export Bulletins are now published in loose-leaf form to provide in a single volume all new regulations, as well as changes in older ones.

WAA Completes Disposal of Electronic Surplus

The War Assets Administration has completed its disposal of surplus radio and electronic equipment, except for the processing of documents and the completion of final auditing reports of agents and distributors.

Out of a total surplus electronic-radio acquisition of $816,307,000, at original cost, the WAA disposed outright of electronic equipment and parts valued at $584,310,000. Approximately $63,672,000 was received in cash. About $300,000,000 worth of radio and electronic equipment was distributed among state, city, and county governments and educational institutions without charge.

[1] The data on which these NOTES are based were selected, by permission, from "Industry Reports," issues of March 18 and 25, and April 1, 8, and 15, published by the Radio Manufacturers' Association, whose helpful attitude in this matter is hereby acknowledged.

Institute Committees—1949

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D. B. Sinclair, *Vice-Chairman*
Haraden Pratt, *Secretary*

W. R. G. Baker
M. G. Crosby
A. N. Goldsmith
B. E. Shackelford

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R. W. Hickman
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Elements of Electromagnetic Waves, by Lawrence A. Ware

Published (1949) by the Pitman Publishing Corp., 2 W. 45 St., New York, N. Y., 200 pages+3-page index+x pages. 69 figures. 6×9¼. $3.50.

The purpose and level of this book is stated by the author as follows:

"This text has been prepared to meet the need for an elementary introduction to the basic ideas of electromagnetic theory. It is intended as first-course material for either juniors or seniors, and the only prerequisites are calculus and the fundamentals of alternating current theory. . . . It is assumed that the reader is familiar with the circuited law of magnetism. . . . A knowledge of Faraday's emf law in line-integral form is also assumed."

It is quite revealing to read this book and learn how many inconsistencies and errors in physics, mathematics, logic, and concepts can be made in a little volume of 200 pages. It is also amusing to observe that the author somehow managed to arrive at correct answers most of the time, in spite of the numerous mistakes in many of the derivations. The following examples represent a small fraction of the errors presented in this book.

First of all, the author does not distinguish among electrostatic, magnetostatic, quasistationary, and electromagnetic problems. For example, on page 41, after stating

$$\oint E \cdot ds = E = -\frac{d\phi}{dt},$$

the author goes on to say that "The analysis of electric and magnetic fields are better carried out in terms of the gradients of the two scalar potentials

$$H = -\nabla \text{mmf} \quad \text{and} \quad E = \nabla\phi,"$$

on the same page. Still on the same page, one finds equation 3.5:

$$B = \mu H = \frac{\phi}{A},$$

a new form of vector analysis where a scalar quantity can be divided by a vector quantity.

As an illustration of mathematical laxity, one finds on page 65:

$$\int_S \nabla \times H \cdot da = \int_S J \cdot da.$$

The two integrals are taken over the same area so that, necessarily, the integrands must be equal, as follows:

$$\nabla \times H = J.$$

The result happens to be correct, provided the J is interpreted correctly.

"In preliminary form," the author states, "the text presented here has been successfully used through two semesters." The assumption might be, consequently, that the footnotes in the book are the results of questions raised by the students. In one footnote (page 125) the author manages to prove that "the real part of $\epsilon^{-\gamma z}\epsilon^{j\omega t}$ is the same as $\epsilon^{-\gamma z}\cos\omega t$" where γ is a complex quantity! The reviewer is reminded of his school days, when he managed in a quiz to prove a theorem in a dubious way, and was proud of his accomplishment. The only difference in the above case is that the theorem is incorrect.

The publishers are to be commended for the excellent appearance of the book, and the fine line drawings.

L. J. Chu
Massachusetts Institute of Technology
Cambridge, Mass.

Photofact Television Course, edited by B. V. K. French

Published (1949) by the Howard W. Sams Co., Indianapolis 7, Ind. 200 pages+5-page index+6-page glossary+5-page bibliography. 250 figures. 8½×11. Bound in boards. $3.00.

This book, based on a series of lectures by Albert C. W. Saunders, describes television principles, operation, and practice for those already familiar with radio techniques. Using the cathode-ray tube as a point of departure, the book is divided into three sections, covering beam formation and control, beam deflection systems, and beam modulation and synchronization. Under those headings, cathode-ray tube construction, camera tubes, voltage supplies, sawtooth generators, sync circuits, control functions, receiving antenna circuits, rf input tuning systems, if systems, video amplification, and many other aspects of the field are analyzed, with diagrams.

Tables of Bessel Functions of Fractional Order, Volume II

Published (1949) by the Columbia University Press, Morningside Heights, New York 27, N. Y. 365 pages+xviii pages. 8×10½. $10.00.

This volume, compiled by the Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards, is devoted to the tabulation of $J_\nu(x)$ for $\pm\nu = \frac{1}{4}, \frac{1}{3}, \frac{2}{3}, \frac{3}{4}$, and is a sequel to the volume containing $J_\nu(x)$ for the same orders. The functional values in both volumes are given either to ten decimal places or to ten significant figures. Tables of the Everett interpolation coefficients, a list of constants, and a table for facilitating interpolation with respect to ν are also included.

The Scintillation Counter*

J. W. COLTMAN†

Summary—**The scintillation counter is a relatively new instrument for the detection and measurement of nuclear and atomic radiations. Light produced in a fluorescent material by the incident particle or quantum is picked up by a photomultiplier tube. The resultant photoelectric emission is amplified in the photomultiplier by a series of secondary-emission stages.**

This paper is a review of the present state of knowledge regarding the characteristics of the counter and the details of its operation.

THE FLASHES of light released when high-energy alpha particles strike a fluorescent screen constituted one of the earliest means of detecting nuclear particles. With such means, several of the classic experiments in radioactivity were performed. As other more convenient and sensitive detectors became available, this early method fell into complete disuse. Recently, however, it has become possible to replace the eye of the observer with an extremely sensitive and rapidly responding device, the multiplier phototube. The resulting detector is one which responds to the individual particles or quanta of all high-energy ionizing radiations, and which thus has a field of application similar to that of the Geiger counter.[1] For many purposes, the higher counting rate of the scintillation detector, its tremendous range of sensitivity, and its high intrinsic efficiency make it superior to the Geiger counter.

An important advantage is that the fluorescent material is a highly absorbing solid, rather than a gas. The phosphor is in an exposed position external to the vacuum envelope of the phototube, and requires no difficult thin-window technique with easily absorbed radiations like alpha rays, beta rays, and soft X rays. Even for very penetrating radiations, the position of the detecting layer is well defined. The new detector is rugged and stable, shows no evidence of temperamental qualities, and appears to have an indefinitely long life.

The detector consists of a photomultiplier tube, such as the RCA 931A,[2] and a fluorescent material mounted external to the envelope. Some system for collecting as much of the light as possible is desirable, and in the arrangement of Coltman and Marshall[3] this takes the form of a hemispherical mirror. Fig. 1 shows the phototube with the fluorescent screen attached, and Fig. 2 the completed detector, with the light-gathering mirror in place. Fig. 3 shows diagrammatically the construction and operation of the detector. The radiation—for example, an alpha particle—enters the window and causes a scintillation within the fluorescent screen. The rays of light from this flash are collected by the light-gathering mirror and focused upon the sensitive area of the photocathode of the multiplier tube. Since the incident quanta or particles of all the radiations for which the detector is used have large energies in comparison with photons of light, and since the energy efficiency of the fluorescent screen in converting these radiations into light is high, each quantum of absorbed radiation results in a very large number of photons of light. Despite light losses in the screen, incomplete collection of light by the mirror, and a yield of only about one photoelectron per ten photons of light at the photoelectric surface, an appreciable number of photoelectrons are ejected from the photocathode for each quantum of detected radiation, thus forming a signal pulse of photoelectrons. This pulse is then amplified by the familiar secondary-emission system of the multiplier tube. Each photoelectron is swept to the first dynode by a potential difference of about a hundred volts, and ejects four or five secondary electrons. These, in turn, are swept to the second dynode and similarly multiplied by secondary-emission amplification. After nine such stages, an avalanche of a million electrons, more or less, appears at the output of the multiplier tube as a result of each initial photoelectron. The output signal pulses are sufficient to operate directly the amplifier of an oscilloscope, though it is usually preferable to introduce one or two intermediate stages. Fig. 4 shows the detector in a compact unit, including power supply and auxiliary stages, ready for operation of an oscilloscope, speaker, or discriminator-scaling-counting system.

The excellent properties of the scintillation detector are due in large part to the unique character of the amplification afforded by the multiplier tube, by which the signal is lifted to a high output level before being released to external circuits. Not only is the response time of the multiplier amplifier extremely short, but the amplification is almost totally free of drift, stray pickup, and resistor noise. One may think of the intermediate step in the new detector, the step by which the original radiation is trans-

* Decimal classification: 621.375.2×535.3. Original manuscript received by the Institute, January 14, 1949.

† Westinghouse Research Laboratories, East Pittsburgh, Pa.

[1] Fitz-Hugh Marshall and J. W. Coltman, "The photomultiplier radiation detector," *Phys. Rev.*, vol. 72, p. 528; September, 1947.

[2] R. B. Janes and A. M. Glover, "Recent developments in photo tubes," *RCA Rev.*, vol. 6, pp. 43–54; July, 1941.

[3] J. W. Coltman and Fitz-Hugh Marshall, "Photomultiplier radiation detector," *Nucleonics*, vol. 1, pp. 58–64; May, 1947.

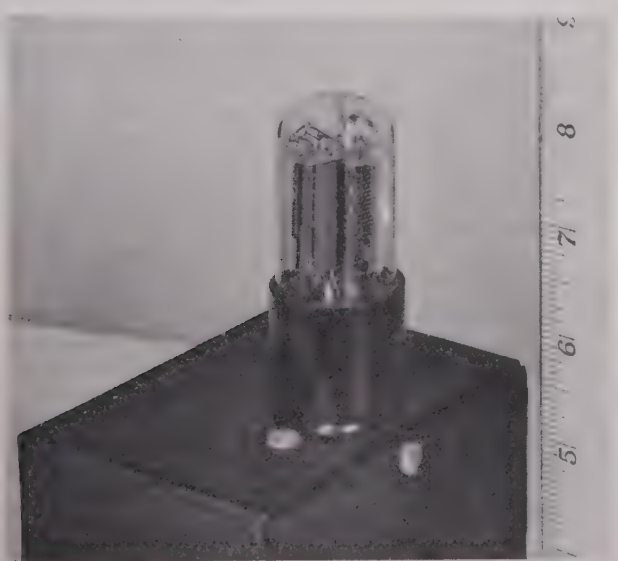

Fig. 1—A photomultiplier scintillation counter without mirror.

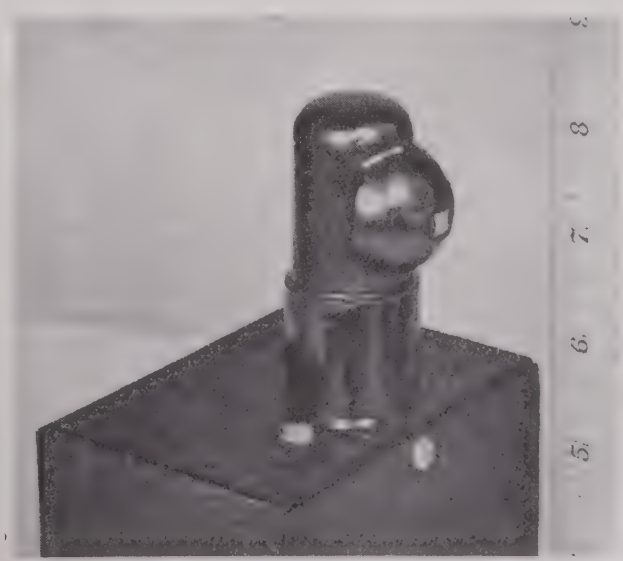

Fig. 2—Complete counter with mirror, window, and light-proof coating.

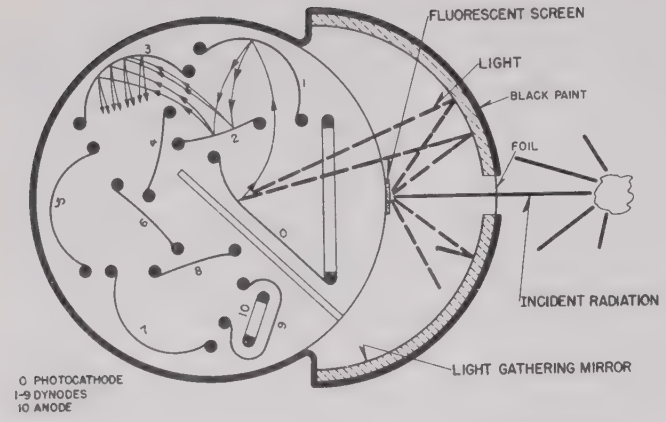

Fig. 3—Schematic diagram of operation of the scintillation counter.

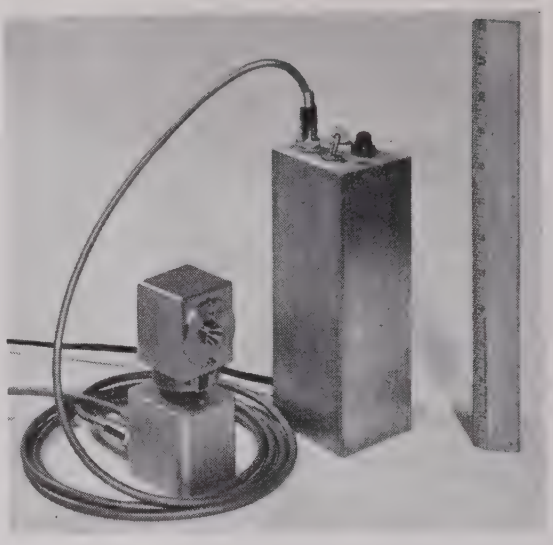

Fig. 4—A scintillation counter with built-in preamplifier and power supply.

formed to light before it is used for release of electrical charge, as being a means by which the multiplier type of amplification can be introduced with a minimum of difficulty. Radiation which may or may not be sufficiently penetrating to traverse a vacuum envelope is transformed to light, which definitely can. Thus a commercial sealed-off multiplier tube is practical, and the pressure of the surrounding atmosphere is thereafter of no importance to the operation of the detector. The question often arises as to whether penetrating radiations might better be allowed to eject photoelectrons directly, without the intermediate step of producing light in the fluorescent screen. With the fluorescent screen omitted from the detector, some response due to direct photoelectric excitation is actually observed with X rays, but only a few of the absorbed quanta give rise to signal pulses, and the number of photoelectrons in these pulses is small. With any known photoelectric material, the efficiency of such a method would be low in comparison to that obtained when the fluorescent process is introduced as an intermediate step. With penetrating radiations, efficiency is inherently low for direct excitation, regardless of the kind of cathode material used. The photoelectrons are produced throughout the depth of the cathode, and most of them are absorbed within the cathode or emerge with energies too high to permit focusing by the electron-optical system of the multiplier. In contrast, when the intermediate fluorescent process is used, radiation energy is effective when transformed into light anywhere within the thickness of the solid fluorescent screen, at least to the extent that the fluorescent material is transparent to light.

While the advantages of multiplier amplification are beyond dispute, the multiplier phototube brings with it two problems of its own. These are dark-current noise and statistical fluctuation in gain for elemental processes. The dark-current noise appears as pulses which tend to overlap the signal pulses in amplitude, determining in this way the low-intensity limit of sensitivity of the detector, at least for radiations characterized by weak signal pulses. The electrode surfaces, having a low work function, as is necessary for good sensitivity to light and to electron bombardment, tend also to release electrons whenever they acquire the higher thermal velocities associated with molecular agitation even at room temperature.[4] Thus a dark current of 10,000 to 100,000 thermal-emission electrons per second, depending on the particular tube, is emitted from the photocathode and from each dynode. Only those emitted from the photocathode receive the full amplification of the tube, and are of primary importance in contributing to noise. On an oscilloscope at the output of the multiplier tube, these noise pulses may be observed individually. They intermingle with any radiation signal pulses which may be present, and tend to obscure them. Only at radiation intensities so high that the signal-pulse rate approaches the noise-pulse rate can the presence of radiation be detected as a general increase in integrated output current as measured by an ordinary dc meter. But even at low intensities, radiation may be detected if the signal pulses have amplitudes sufficiently greater than the noise pulses. The output may then be passed to a discriminator circuit which delivers to a scaling-counting-circuit meter only those pulses above a selected amplitude.

Each noise pulse is associated with emission of a single thermal electron, whereas, ideally, each signal pulse is associated with the emission of an appreciable number of photoelectrons. Since signal-pulse detection is possible only to the extent that the signal-pulse amplitude is greater than the noise-pulse amplitude, it is exceedingly important that the detector be made as efficient as possible in the production of photoelectrons at the photocathode. To this end, the number of photoelectrons per radiation quantum absorbed must be made as great as possible by the proper choice of fluorescent screen, by the use of reasonably efficient light-collecting systems, and by the use of a selected multiplier phototube. Also, the distinction between signal and noise pulses must be maintained as carefully as possible by the use of a proper external circuit. These precautions are desirable for all radiations, and are essential to good low-intensity sensitivity for radiations yielding weak pulses. The output amplitudes of both signal and noise pulses vary widely, because of the statistical nature of the amplification at the various stages of the multiplier and other factors. Since the noise pulses are so numerous and the spread of amplitudes so great, the tendency to overlap extends to much greater signal-pulse amplitudes than might, at first, be expected.

Several experimenters have resorted to cooling the photomultiplier tube with dry ice or liquid air, at which temperatures the dark-current pulses may be almost completely eliminated.[4] While this procedure is very effective, and particularly useful in studying the characteristics of the detector, the method is very inconvenient and, in most cases, unnecessary. Signal pulses have been successfully separated from noise pulses simply by the use of efficient phosphors, good light collection, and proper attention to the associated circuits.

Photomultiplier Tubes

Only a very few types of photomultiplier tubes are commercially available. Of these, the RCA 931A has been most widely used. It has a photocathode surface of cesium antimony, with a spectral response curve as given in Fig. 5.

The 1P21 tubes are identical with the 931A in construction, but have been especially selected by the manufacturer for better over-all sensitivity, which is considerably above that of the average 931A.

The 1P28 has the same internal construc-

[4] R. W. Engstrom, "Multiplier phototube characteristics: application to low light levels," *Jour. Opt. Soc. Amer.*, vol. 37, p. 420; June, 1947.

tion as the 931A, but is enclosed in an envelope of ultraviolet-transmitting glass which extends the spectral response of the tube well into the ultraviolet. The 1P22 utilizes a cesium-bismuth photosurface which has a spectral response much further into the red, but has greatly reduced total sensitivity.

Recently RCA has made an experimental photomultiplier, designated the C7132, which departs radically from the construction of the other types. The photocathode is transparent and deposited on the inside of the end of the cylindrical envelope. It is 1½ inches in diameter, an area some 150 times that of the sensitive area of the 931A, and is almost directly accessible to the exterior, so that good light collection is assured. Though no reports are available as to its performance as a scintillation counter, the geometry is certainly excellent for this purpose.

All of these tubes have one characteristic in common—they are extremely variable from one sample to the next. Because it is very difficult to control accurately the properties of the photoelectric and secondary-emission surfaces, and because any factor which affects the sensitivity of all the surfaces is raised to the 10th power, it is little wonder that the over-all sensitivity varies so much from tube to tube. In addition, the amount of noise current generated in the tube varies over a wide range. For use as a scintillation counter, the gain and sensitivity are of little importance, for the output of the tube is well up to where simple amplifiers may be used. The important characteristic is the signal-to-noise ratio, i.e., the response to available amounts of light as compared to the dark current. Since some of the dark current occurring at the anode is simply dc leakage, it is important that only the ac component (shot noise) of the dark current and signal currents be compared.

Marshall, Coltman, and Bennett[5] have made comparative measurements on fifty-three 931A tubes bought from unused war surplus stock, using a wide-band ac voltmeter connected to the output of the photomultiplier. The voltmeter reading with no light admitted to the phototube served as a measure of noise. The increase of voltmeter reading with the introduction of a standard feeble beam of light upon the photocathode served as a measure of signal. The appropriate ratio of these two values then provided a relative signal-to-noise ratio which served satisfactorily for arranging tubes in the order of their merit. The standard light beam used was crudely collimated, was smaller in cross section than the photosensitive area, and was directed perpendicularly through the electrostatic shielding grid to the position on the cathode showing maximum response. Measurements were made quite rapidly. Once set, the geometry was not varied as successive tubes were introduced into the rigidly mounted socket, the position of maximum response having been found not to vary appreciably from tube to tube. The light intensity was set so low that the increase in meter reading for light was never more than a few times the reading for noise alone. The actual ratios are shown as abscissas in Fig. 6. Unfortunately, the optical system used for reducing the light intensity involved a number of elements and could not be specified accurately enough to permit duplication by others for the purpose of comparing single tubes with their results.

The histogram of Fig. 6 shows the results of the measurements. Most of the tubes are seen to be very poor in comparison to those in roughly the upper 20 per cent which proved to be satisfactory when made into detectors. No correlation whatever was found between signal-to-noise ratios and output sensitivity as indicated by the signal values obtained in these tests. When installed in radiation detectors, the tubes have been found to be effective in the order expected from the histogram within the limits of simple oscilloscopic comparison.

An ac meter was used for these measurements so as to eliminate the dc component of the dark current arising from resistive leakage in the output stage of the multiplier tube. This leakage, which does not contribute measurably to noise, is partly internal along the coating of condensed cesium between the elements of the tube, and it cannot always be eliminated or easily measured. The meter used was a Ballantine Model 300 voltmeter, which has a bandwidth of 150 kc. In this instrument the signal is amplified and passed through a full-wave rectifier, so that the meter indicates the average of absolute values of fluctuations impressed upon it.

It is fairly evident that signal-to-noise ratios obtained in these tests are independent of the gains of later stages of the multiplier tube. Instead, they tend to be related only to the very-early-stage pulse events, which are thus of primary concern. The obvious practical success of the method arises from the fact that the signal-to-noise ratios have to do essentially with photocathode

[5] Fitz-Hugh Marshall, J. W. Coltman, and A. I. Bennett, "Photo-multiplier radiation detector," *Rev. Sci. Inst.*, vol. 19, pp. 744–771; November, 1948.

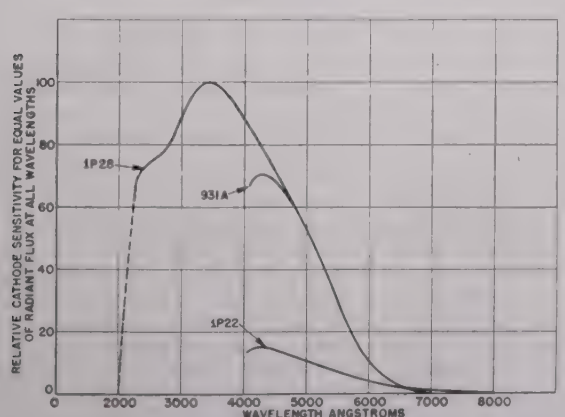

Fig. 5—Relative cathode response of various photomultiplier tubes as a function of the wavelength of the received light.

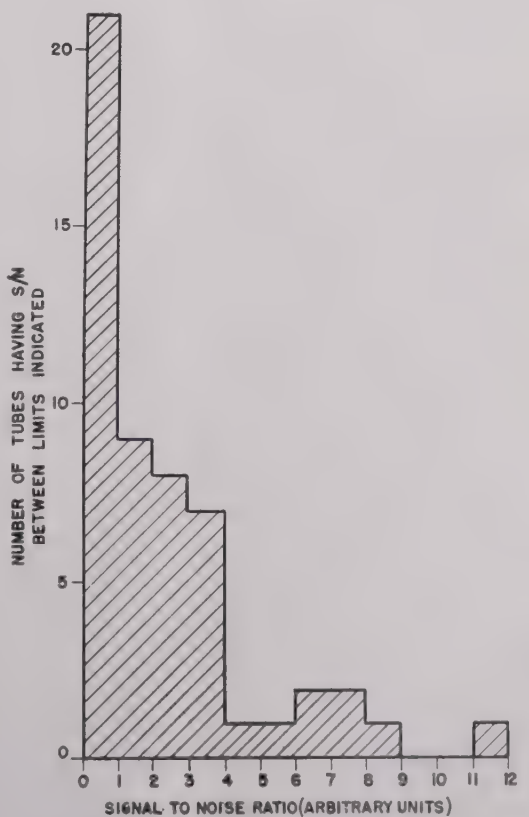

Fig. 6—Distribution of fifty-three 931-A tubes with respect to signal-to-noise ratio.

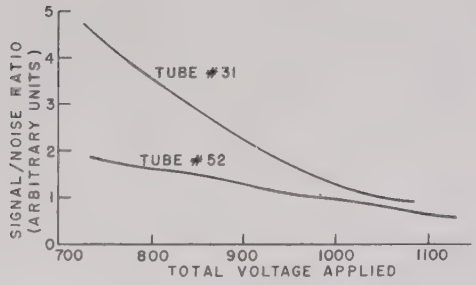

Fig. 7—Variation of signal-to-noise ratio with dynode voltage for two typical 931-A's.

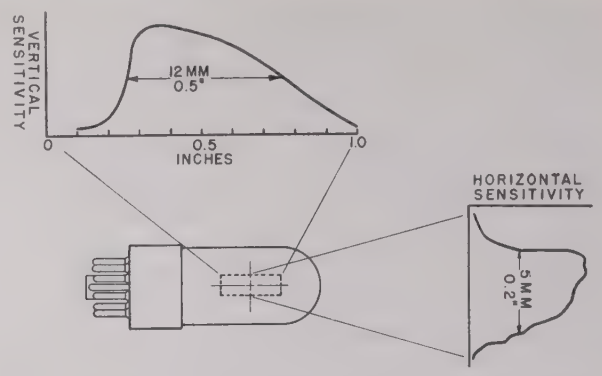

Fig. 8—Variation of sensitivity across the width and length of the photocathode of a 931-A tube.

sensitivity to light and with cathode dark current. Beyond this point there is some question as to exactly what is measured, and even as to what is most desired. For low pulse rates, as in the measurement of low thermal-emission currents, the pulses are probably largely resolved by the meter amplifier, and the meter reading tends to be proportional to the pulse rate. At high pulse rates the pulses may be poorly resolved, so that the reading tends toward proportionality to the square root of the pulse rate. Such a scale distortion may weight the signal-to-noise ratios in a way to favor tubes with unusually low cathode noise-pulse rates. It is questionable whether this is strictly desirable.

The variation in signal-to-noise ratio as a function of applied dynode voltage is shown for two typical tubes in Fig. 7. The curves suggest that it is generally advisable to operate at the lowest voltages that will yield sufficient gain; about 80 volts per stage is usually satisfactory. While the majority of tubes tested show a drop in signal-to-noise with increased voltage, a very few exhibit a slight improvement in signal-to-noise ratio as the voltage is increased.

Some difficulty is occasionally experienced with noise due to external electrical leakage. The chief source is corona leakage in the socket into which the tube is inserted, between the cathode terminal, which is operated at a high negative potential, and the adjacent anode terminal, which is operated near ground potential. This source of noise can be completely eliminated by removing the anode terminal lug from the socket, drilling out the socket, and inserting a new tubular pin grip surrounded completely by a polystyrene cylinder which is shielded, in turn, by a thin grounded metal tube. There is also leakage in the tube base itself, but this leakage seems to be purely resistive and does not contribute measurably to noise. While of no importance in the pulse detector, variations in this leakage are sometimes annoying in dc measurements; they can be reduced by removing the anode pin from the base of the tube, drilling a rather large hole through the side of the base for easy access, and connecting a polyethylene-insulated wire directly to the anode lead at the base of the glass envelope of the tube. Noise is also introduced when grounded conductors are permitted to contact the glass envelope of the tube, so that shielding or light-proofing coatings must either be insulated from ground or kept from touching the glass. The cause of this phenomenon has not been determined.

Many factors associated with noise, gain, and cathode photosensitivity in the multiplier phototube are poorly understood. For example, there is no indication whether the large variations in signal-to-noise ratio shown in Fig. 6 are primarily attributable to variations in cathode photosensitivity or in cathode noise. As another example, the increase in noise with dynode potential, as shown in Fig. 7, is not fully understood. Engstrom[4] mentions that the increase of noise with dynode potential may be associated with ionic feedback from the anode to the cathode. Also, it is difficult to explain Richardson plots determined experimentally for the photosurface, and to correlate them with work functions as indicated by the observed long-wavelength cutoff.[4]

The results of the signal-to-noise measurements, together with the performance of these tubes as scintillation counters, indicate that only about one tube out of five will be satisfactory for counter use. It appears that tubes should be selected on the basis of signal-to-noise ratio, a requirement which is not met by existing procedure in photomultiplier production. Though the 1P21 is a selected tube, the manufacturer has in the past based the selection on overall sensitivity, which would appear to bear little or no relation to the signal-to-noise ratio.

A characteristic of the photomultiplier which must be considered is the area and location of the sensitive portion of the photocathode. Though the entrance grid on the 931A is approximately 1 inch by ½ inch, the useful cathode area is very much smaller, because only photoelectrons ejected from a certain rather narrow region will be carried to the first dynode by the focussing field.

The size and shape of the useful photosensitive area on the photocathode has been measured[5] for a number of 931A tubes. To simplify the process of measurement of a large number of tubes, an arrangement has been used whereby a line along the cathode was scanned rapidly with a 13-mil beam of light directed perpendicularly through the electrostatic shielding grid, and the response of the tube observed on a synchronized oscilloscope. Typical central traces along the width and length of the cathode are shown in Fig. 8. All tubes tested exhibited the asymmetry of vertical sensitivity shown in the figure. The shape of these curves, of course, is primarily determined by the electron-optical focusing properties of the electrode system, and does not indicate true variation of photosensitivity over the cathode. The potential difference per stage was 100 volts. No tests were made of change of size of photosensitive area with applied potential or of variation in sensitivity with angle of incidence of the light upon the cathode surface.

The tubes were found to be quite consistent, the width at half-maximum sensitivity varying not more than ±10 per cent. Despite the asymmetry in the vertical curve, the sensitive area, measured to points of half-maximum sensitivity, is approximately centered in the vertical direction midway between the mica spacers at the top and bottom of the cathode. In the horizontal direction the sensitive area is approximately centered along the projected midline of the entrance grid.

Phosphors

The search for suitable fluorescent materials for use in scintillation counters at present still proceeds at a rapid pace. Since the desired characteristics for this use differ markedly in certain respect from those required in ordinary applications, many materials which are usually considered inferior have proved to give better results than the more usual phosphors.

For highly penetrating radiations, such as gamma and beta rays, the phosphor must be relatively thick if high absorption (i.e., good counting efficiency) is desired. In order that the fluorescent light may reach the photocathode, it is, of course, necessary that the material be relatively transparent to the light wavelengths emitted. For very thick sections, the usual finely divided

crystalline materials are quite opaque and are thus at a considerable disadvantage, even though they may have a relatively high intrinsic conversion efficiency.

The attention of most experimenters has turned toward materials which can be obtained in large clear pieces, and some effort has been expended in growing single crystals of various materials for this use. However, for readily absorbed radiations, such as alpha particles, X rays, and low-energy beta rays, the materials in powder form can be used quite effectively, especially if some optical system such as the mirror of Fig. 3 is employed.

It is very difficult to compare in a rigorous manner the effectiveness of the various phosphors. Ideally, one would like to know the intrinsic efficiency of the luminescent process, i.e., the light energy generated by the crystal for a given energy absorbed from the exciting radiation. In addition, the absorption of the crystal for the exciting radiation, the efficiency of transfer of the fluorescent light from the crystal to the photosurface, and the spectral distribution of the emitted light should be known. Unfortunately, it is quite difficult to determine any of these factors.

Almost all observations taken consist simply of measuring the number of counts obtained with a given source of radiation. Usually a distribution curve of pulse heights is also taken, which may sometimes enable one to get a measure of the relative pulse heights for different materials. This appears to be a straightforward-enough method; yet it is beset with many uncertainties. First, results from different experimenters are almost impossible to compare unless they have each measured a common sample; for the geometries, radiation sources, and electronic equipments are bound to differ, often in important respects. Second, it is not easy to interpret the data taken on different materials, even with the same apparatus. As will be enlarged upon later, the distribution curves of pulse heights from a single sample have a shape somewhat similar to a hyperbola, so that the extrapolation to zero pulse height is often very uncertain. Without a knowledge of total number of pulses, the true average pulse height cannot be obtained. In spite of this, there is very great temptation to estimate pulse heights from visual observations. This is a dangerous procedure, for the *apparent* average pulse height is greatly affected by the pulse rate, which is a function of the absorbing power of the material as well as its intrinsic efficiency. In a few clear-cut cases, the differential bias curves (distribution of pulses according to height) show sufficient difference in slope when plotted on a logarithmic scale to enable meaningful statements as to the relative efficiencies of various phosphors to be made.

In spite of these drawbacks, the tests usually performed have the virtue that they represent the practical performance of a given sample, at least under the conditions of the test. What is perhaps an even worse state of affairs is the notorious variability of fluorescent substances. The fluorescent properties of many of the interesting materials depend on the presence of minute amounts of a foreign substance, or a very slight stoichometric excess of one of the constituents. It is possible to manufacture phosphors with reasonably uniform properties only when extreme measures are taken to control rigidly the purity of the materials, and all the steps in the processing. Naturally occurring materials are, of course, likely to vary widely in their fluorescent properties. Until more work is done on separating factors responsible for the behavior of a given phosphor sample, it will be difficult to correlate results of experiments, and a certain amount of disagreement between experimenters is to be expected.

The first materials successfully used for counting gamma and beta rays were silver activated zinc sulfide[1] and naphthalene.[6] The first material has a very high intrinsic efficiency (X-ray measurements indicate roughly 50 per cent), but its finely divided form prevents its being used in thick sections, and its relatively long decay time (20 microseconds or more) is prone to give rise to multiple counting. Most of the experimenters have compared their materials with naphthalene, and so it has, in a sense, become a standard of comparison. However, there are no published data on the variations of naphthalene from sample to sample, nor is there a generally accepted procedure for making comparisons, so that no real standard exists as yet. Moon[7] published results on twenty-eight inorganic materials tested with 1P28 and 1P21 photomultipliers using radium gamma rays as a source. The list is divided into categories of excellent, fair, medium, weak, and no "response." Listed as excellent are $CaWO_4$ (Scheelite) CaF_2 (Fluorite) $LiAlSi_2O_6$ (Spodumene) Al_2O_3 (synthetic sapphire) and LiF (synthetic). $CaWO_4$, in the form of a large, clear natural crystal about 7 by 10 by 1.1 mm, was said to be by far the best, and yielded about three times the gamma counting rate obtained with a much larger (11 by 16 by 45 mm) naphthalene crystal. No pulse-height measurements are reported.

Bell[8] has reported that anthracene, in the form of large, clear pieces crystallized from the melt, is much more effective than naphthalene. His pulse-height distribution curves show the total numbers of pulses (extrapolating to zero pulse height) as equal for the two materials, yet the anthracene pulses are about three times as high using gamma radiation, and five times using alpha particles.

Collins and Hoyt[9] report that anthracene, naphthalene, diphenyl, and a $BaSO_4$ +6 per cent $PbSO_4$ phosphor are effective with radium beta rays, but do not ascribe an order to their effectiveness.

Hofstadter[10] reports some work with crystals of KI and NaI activated with small amounts of thallium. The NaI appears to be a much more efficient phosphor than naphthalene, although the distribution curves do not afford a quantitative measure of pulse height or counting rate, for the distributions appear to be quite different, and the choice of bias setting (which determine the minimum pulse height counted) greatly affects the relative counting rate.

A private communication from Hofstadter indicates that NaI(Tl) gives about 1.5 times the pulse height of anthracene, and that apparently this material is the most effective known at the present time.

Before the true status of the various materials can be properly evaluated much work remains to be done. The NaI(Tl) appears to have a relatively high intrinsic efficiency, but it is doubtful if it approaches that of ZnS(Ag). Under X rays, a natural $CaWO_4$ crystal is quite noticeably weaker in visible fluorescent light yield than a good X-ray screen of synthetic $CaWO_4$. The intrinsic efficiency of the latter is known[11] to be 5 per cent for 80 kv X rays, while that of ZnS(Ag) is probably about 50 per cent. Though no direct comparison of NaI(Tl) with $CaWO_4$ is at hand, one would guess from the above references that NaI(Tl) is not more than three times as efficient as the natural $CaWO_4$. It would appear, then, that there is at least theoretically room for considerable improvement.

It should be emphasized again that conditions of an experiment will greatly affect its results. For example, the spectrum of emitted light from naphthalene is believed[6] to extend well into the ultraviolet, so that experiments with the 931A, which cuts off at about 3500A°, may favor other materials with a spectrum nearer the visible but with less total output. Again, when the decay time of the phosphor is not very small with respect to the time constants of the amplifier circuit, the spreading of the pulse in time lowers the relative height, even though the area (representing total light in the pulse) may be large.

The experiments have, however, turned up several materials which give excellent results, and the place of the photomultiplier scintillation counter as a detector seems to be assured, together with promise of considerable improvement in the near future.

Optical Systems

For greatest possible discrimination between signal pulses and dark-current pulses, attention must be given to collecting as much light as possible from the phosphor. Rough computations based on the variation of sensitivity over the cathode (Fig. 8) and its geometrical configuration indicate that, for a small screen mounted directly on the envelope, the response is only 1/30 of that which would be obtained if all the light were directed to the most sensitive spot. These calculations assumed a Lambertian distribution of light from the screen, but did not take into account possible variation of photosensitivity with angle of incidence of the light.

When relatively large crystals are used for the phosphor, it is evident that only a

[6] H. Kallmann, *Natur und Technik*, July, 1947.
[7] Robert J. Moon, "Inorganic crystals for the detection of high-energy particles and quanta," *Phys. Rev.*, vol. 73, p. 1210; May 15, 1948.
[8] P. R. Bell, "The use of anthracene as a scintillation counter," *Phys. Rev.*, vol. 73, pp. 1405–1406; June 1, 1948.
[9] George B. Collins and Rosalie C. Hoyt, "The detection of beta rays by scintillations," *Phys. Rev.*, vol. 73, p. 1259; May 15, 1948.
[10] Robert Hofstadter, "Alkali halide scintillation counters," *Phys. Rev.*, vol. 74, pp. 100–101; July 1, 1948.
[11] J. W. Coltman, E. G. Ebbighausen, and W. Altar, "Physical properties of calcium X-ray screens," *Jour. Appl. Phys.*, vol. 18, pp. 530–544; June, 1947.

small fraction of the light will be collected from each scintillation. By wrapping the crystal in bright aluminum foil except for the face adjacent the tube, an improvement can be obtained which may be of the order of two times, depending on the geometry and transparency of the crystal.

For low-penetrating radiations such as soft beta rays, X rays, and heavy particles, a thin phosphor layer can be used; and, if the reduced area can be tolerated, the mirror system of Coltman and Marshall[12] provides the gain which is almost essential for low-energy radiations.

The dimensions of the sensitive cathode area and the magnification of the mirror system determine the maximum useful size of the fluorescent screen. Measured to points of half-maximum sensitivity in Fig. 8, the dimensions of the sensitive cathode area are about 5 mm by 12 mm. The mirror has a magnification of about two. For this mirror therefore, a fluorescent screen size of 2.5 mm by 6 mm gives an image which approximately covers the sensitive area on the cathode.

The mirror was made from the hemispherical bottom of a Corning T-10 glass bottle, cut off with a wet carborundum wheel, and ground to the dimensions shown in Fig. 9. The inside surface is aluminized by vacuum evaporation.

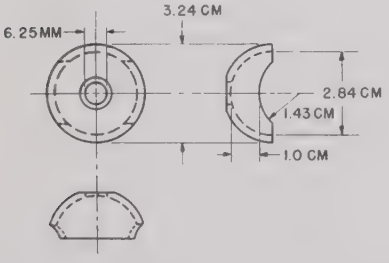

Fig. 9—Dimensions of an effective light-gathering mirror.

In the final assembly, the position of the mirror on the tube envelope is adjusted individually for each unit. The phosphor is first strongly excited by daylight, causing a faint phosphorescence which persists for several minutes after the tube is taken into the dark. With a vacuum-tube voltmeter used as a dc microammeter to measure anode current, the position of the mirror for maximum response is then located. At the same time the phosphorescing screen provides a means for measuring the effectiveness of the light-gathering mirror. Response with the mirror in place has been found to be about five times that from the phosphor alone without a mirror.

It is necessary, of course, to exclude external light from the tube when in operation. For most purposes this requires the use of either a light-proof coat of black laquer, or a small enclosure around the tube, and, for most radiations, an opaque thin window. Perhaps the most satisfactory window material is beaten aluminum leaf. This can be obtained as thin as 0.00003 inch (0.18 mg/cm²) from M. Swift and Sons, 10 Love Lane, Hartford, Conn. Because of small pinholes, it is best to use two thicknesses, which still have a very small stopping power, even for alpha particles.

The enclosure shown in Fig. 4 has the mirror attached to the inside wall of the box rather on the phototube, and the window mount includes a convenient provision for simultaneously punching out a round disk of the aluminum leaf and securing it in position.

Circuit Considerations

The type of amplifier used with the scintillation counter will be dictated to some extent by the intended use of the counter. For alpha particles, where the response is extremely high, it is possible to operate a pair of headphones directly from the anode of the photomultiplier.[13] For operating discriminating circuits, some form of preamplifier is desirable, and its design will depend on the maximum counting rate desired, and on the fluorescent decay characteristics of the phosphor.

While decay times of naphthalene and anthracene phosphors are apparently extremely short, other useful phosphors have measurable decay times ranging from 0.6 to 20 microseconds.[14] The time constants of the amplifier will have a distinct influence on the ratio of signal pulse heights to dark current pulse heights, and it is worth while to design the amplifier for optimal performance, at least in the case of the lower-energy radiations. The considerations governing amplifier design will be discussed in some detail, not only for their practical importance, but because of the insight which they afford into the detection process itself.

The resolving time of the multiplier tube itself is of the order of 10^{-8} second, this limit being set by variations in the 10^{-7}-second total transit time for electrons through the successive multiplier stages. Approximately stated in round figures, each electron (10^{-19} coulomb) leaving the cathode gives rise to an avalanche of 10^{6} electrons (10^{-13} coulomb) at the anode, spread over a time of 10^{-8} second. With the anode capacitance reduced to the minimum of 10^{-11} farad, and with the anode output resistance set at 10^{3} ohms to provide an RC time constant matching the resolving time of the tube, such a pulse might appear at the anode as a potential swing rising to 10^{-2} volts and persisting for 10^{-8} second. The dark-current noise of a selected 931A tube is made up of perhaps 20,000 such pulses a second, randomly distributed in time. These pulses vary considerably in amplitude because of large statistical fluctuation in gain in the early stages of the multiplier, where the number of electrons carrying the pulse is still small. If an oscilloscope with the necessary sensitivity and resolving time were available, the dark-current noise might appear as in Fig. 10(a). In this figure and in those which follow, a single extraordinary

[12] J. W. Coltman and Fitz-Hugh Marshall, "Photomultiplier radiation detector," *Nucleonics*, vol. 1, pp. 58–64; November, 1947.

[13] R. Scherr, "Scintillation counter for the detection of α-particles," *Rev. Sci. Instr.*, vol. 18, pp. 767–771; October, 1947.

[14] Fitz-Hugh Marshall, "Microsecond measurement of the phosphorescence of X-ray fluorescent screens," *Jour. Appl. Phys.*, vol. 18, pp. 512–519; June, 1947.

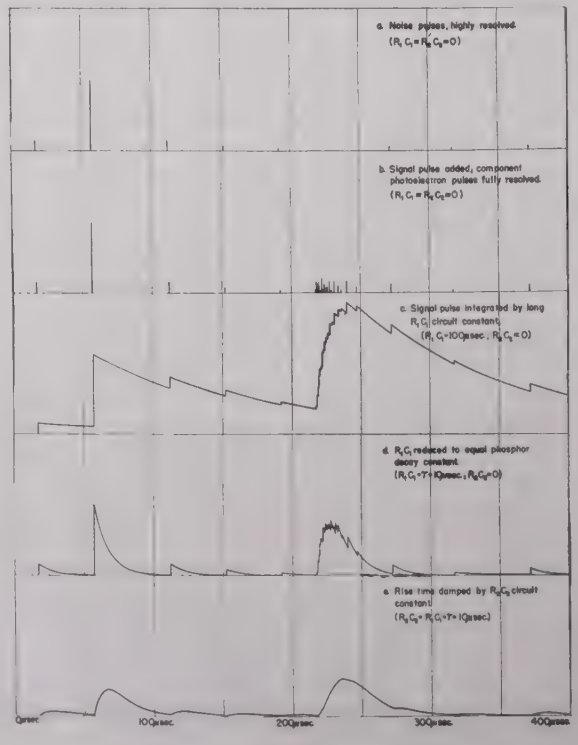

Fig. 10—Effect of circuit constants on noise and signal pulses.

large noise pulse is included at the left to represent one which can be discriminated against only with difficulty; otherwise, the distribution of amplitudes and spacing is typical.

Let us now consider a signal pulse, from a beta particle, say, which results in the emission of 20 photoelectrons at the photocathode. Although the stimulation of the fluorescent screen by the beta particle is essentially instantaneous, emission of light is spread over an appreciable interval of time because of phosphorescent persistence of the screen. The intensity is a maximum at the instant of stimulation, and then drops off according to the decay curve of the phosphor; for the present example we may think of this curve as exponential, with a decay time constant of ten microseconds. Such a signal pulse, as it might appear at the phototube anode, is shown in Fig. 10(b), superimposed upon the pattern of noise pulses carried over from the previous figure.

It now becomes clear that a circuit time constant of 10^{-8} second would be an unfortunate choice, for it would resolve a signal pulse into its component photoelectron pulses, as illustrated in Fig. 10(b). The component photoelectron pulses average no more in amplitude than noise pulses. A discriminator set to miss the high noise pulse at the left in the figure would also completely miss the signal pulse, even though the total charge associated with the latter happens to be greater than that of the large noise pulse. This difficulty can be avoided by using a circuit time constant long enough to integrate the signal pulse.

Fig. 10(c) shows the effect of a high resistance across the output of the multiplier tube such that the anode *RC* time constant is 100 microseconds. Since this is large in comparison to the decay constant of the phosphor, integration of the total charge associated with the signal pulse is almost as complete as it would be with an infinite circuit time constant, and the signal pulse is properly shown rising well above the amplitude of the large noise pulse at the left, permitting easy discrimination on the basis of amplitude. However, this time constant is too long; the trace does not let down sufficiently between noise pulses, which occur on the average once ever 50 microseconds, and the maximum signal-pulse counting rate is unduly low.

In Fig. 10(d) the other extreme is illustrated. The anode circuit time constant is set at 10 microseconds, equal to the decay constant of the screen. Though the response drops down almost completely between noise pulses, and though the counting rate is about as good as the decay time of the phosphor will permit, a new difficulty has arisen. The peak amplitude of the signal pulse in relation to that of the large noise pulse has begun to fall off appreciably and no longer approximates the sum of the componet photoelectron pulses. However, if we should choose to retain this shortened circuit time constant for purposes of fast counting or otherwise, the loss in signal-pulse amplitude can be approximately balanced by the introduction of another circuit device by which the noise pulse amplitude is also reduced.

Fig. 10(e) shows the effect of adding a second circuit time constant, also of 10 microseconds duration, designed primarily to control the rate of *rise* of potential. This damps out the initial fast-rising swing of the noise pulse, without greatly affecting the more slowly rising signal pulse. At the same time, it increases somewhat the pulse duration. With the initial sharp peak of the noise pulse cut off by this second circuit, the distinction originally inherent between the signal and noise pulses by virtue of their total charges may again be closely realized, even though the time constants used may approach the decay time of the fluorescent screen.

The basic circuit for introducing these two time constants is shown in Fig. 11. R_1C_1 is the anode-circuit time constant which controls the rate of fall so as to integrate the signal pulse. R_2C_2 is the constant introduced to control the rate of rise. As will be shown in the next section, these constants are best set approximately equal to the decay constant of the fluorescent screen. The simple *RC* networks chosen to adjust the frequency characteristics of the system are not necessarily the most effective networks for the purpose of obtaining optimal signal-to-noise pulse discrimination. However, as will be shown, the results obtainable are quite close to the optimum.

The features pointed out above in the discussion of signal and noise pulse characteristics are strikingly demonstrated in the high-speed oscillogram of Fig. 12, which was made under approximately the conditions assumed in Fig. 10(c), though with a shorter circuit time constant. In this oscillogram time increases from left to right, but each successive trace appears at a higher position than the last. The time for one complete sweep is 200 microseconds, the gap near the middle of each trace being a 100-microsecond time marker. Signal pulses from P^{32} beta rays are included in the upper part of the figure, the largest shown being well below the maximum amplitude observed. The component photoelectron pulses making up these signal pulses are clearly resolved as steps, the statistical variations in amplitude and spacing being quite evident. The decay of the Patterson Type-D fluorescent screen is not exponential, and persists longer than might be expected from the initial decay rate. The middle part of the figure shows only background noise pulses, being a fairly typical section of the recording made while the beta rays were blocked off. The bottom part of the figure also shows only noise pulses, but it is selected to include an exceptionally large noise pulse. Although this large pulse is distinctively different in appearance from signal pulse, being characterized, as always, by a sharp rise and an unbroken exponential fall, it has a greater amplitude than many of the signal pulses recorded; with a reasonable discriminator setting, it would ordinarily be counted as a signal pulse.

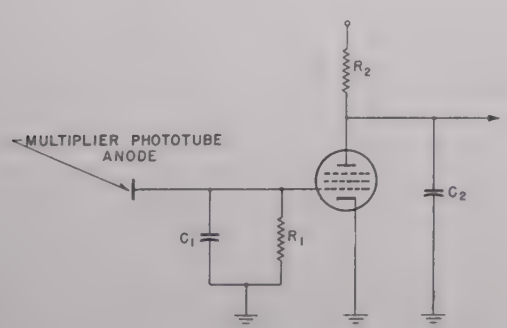

Fig. 11—Basic circuit for introducing R_1C_1 and R_2C_2 time constants.

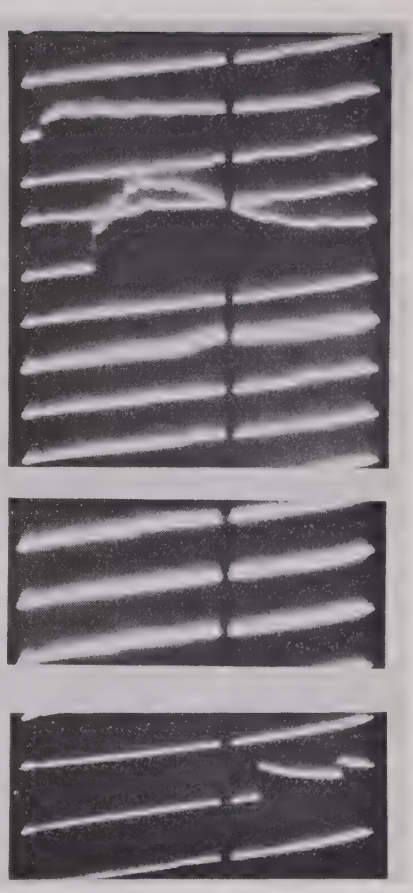

Fig. 12—Oscillograms of a beta-ray pulse (upper), noise pulses (middle), and an exceptionally large noise pulse (lower).

The oscillogram of Fig. 12 brings out the somewhat unusual situation that arises in the multiplier anode circuit with respect to resolving time. The R_1C_1 time constant applies a resolving time only during the fall of the response. The resolving time for the rise is essentially instantaneous, and is unaffected by the R_1C_1 constant. This instantaneous rise has some interesting consequences. It makes possible the resolution of the individual photoelectron pulses in the signal pulses in the oscillogram. On the other hand, the R_2C_2 time constant later in the circuit is required if the rise rate is to be slowed down to match the response time of the fluorescent screen.

Derivation of Optimal Circuit Constants

The most suitable values for the circuit time constants R_1C_1 and R_2C_2 may be determined by mathematical analysis. For convenience, the phosphorescent decay of the fluorescent screen can be assumed to be exponential with a decay time constant. This approximation is justifiable in view of the noncritical nature of the results obtained. With the circuit taken as having the basic form shown in Fig. 11, equations for signal pulses and noise pulses at the pentode anode can be derived, and from these the ratio of their maximum amplitudes can be obtained. The variation of this ratio may be plotted for various values of R_1C_1 and R_2C_2 to permit selection of the optimal values. The analysis proceeds as follows.

Let the total charge Q due to a signal pulse be delivered to the multiplier anode in Fig. 11, according to the exponential decay law

$$I_g = \frac{Q}{\tau} e^{-t/\tau} \tag{1}$$

where I_g is the multiplier anode current or pentode grid current at the time t after the start of the signal pulse, and τ is the decay time constant of the excited phosphor. Since the current I_g divides between the resistance R_1 and the capacitance C_1,

$$\frac{Q}{\tau} e^{-t/\tau} = \frac{E_g}{R_1} + C_1 \frac{dE_g}{dt} \tag{2}$$

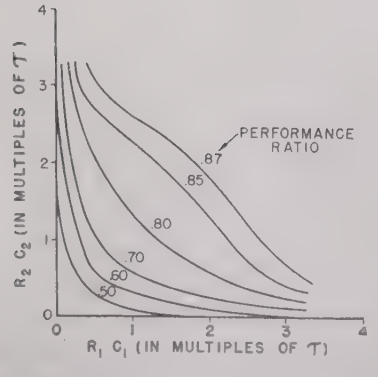

Fig. 13—Contours of circuit performance ratio (signal pulse amplitude versus noise pulse amplitude for the same total charge) as a function of the circuit time constants.

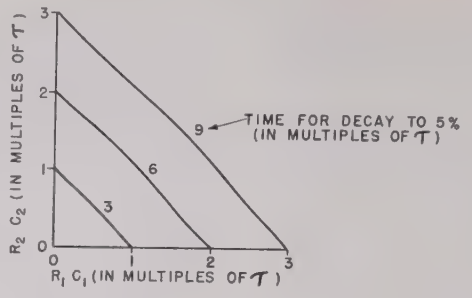

Fig. 14—Contours of time required for a noise pulse to subside to 5 per cent of maximum amplitude, as a function of the circuit time constants.

where E_g is the grid potential. The solution of this differential equation is

$$E_g = \frac{Q}{C_1} \frac{R_1C_1/\tau}{1 - R_1C_1/\tau} (e^{-t/\tau} - e^{-t/R_1C_1}). \tag{3}$$

The plate current of the pentode is then $I_p = g E_g$, where g is the transconductance of the tube. Since the plate current divides between the resistance R_2 and the capacitance C_2,

$$g \frac{Q}{C_1} \frac{R_1C_1/\tau}{1 - R_1C_1/\tau} (e^{-t/\tau} - e^{-t/R_1C_1}) = \frac{E_p}{R_2} + C_2 \frac{dE_p}{dt} \tag{4}$$

where E_p is the plate potential. The solution of this differential equation is

$$E_p = g \frac{Q}{C_1} R_2 \frac{R_1C_1/\tau}{1 - R_1C_1/\tau} \left[\left(\frac{R_1C_1}{R_1C_1 - R_2C_2} - \frac{1}{1 - R_2C_2/\tau} \right) e^{-t/R_2C_2} + \left(\frac{1}{1 - R_2C_2/\tau} \right) e^{-t/\tau} - \left(\frac{R_1C_1}{R_1C_1 - R_2C_2} \right] e^{-t/R_1C_1} \right]. \tag{5}$$

Given τ, this equation for the emerging signal pulse as a function of time can be maximized and the maximum pulse height thus determined.

For a noise pulse, let the total charge again be Q. We may represent the fact that this charge arrives instantly at the multiplier anode by letting $\tau = 0$. Then (5) simplifies for the noise pulse to

$$E_p' = g \frac{Q}{C_1} R_2 \frac{R_1C_1}{R_1C_1 - R_2C_2} (e^{-t/R_1C_1} - e^{-t/R_2C_2}) \tag{6}$$

The ratios of the maximum amplitudes of E_p and E_p', which incidentally do not occur at the same values of time t, may be determined by graphical methods for various values of R_1C_1 and R_2C_2 and are plotted as contours in Fig. 13. The curves are symmetrical with respect to the axes. Since the same total charge Q was assumed for both types of pulse, the best possible value for the ratio plotted in the figure is unity. As might be expected, the circuit fails to maintain this perfect ratio for finite values of R_1C_1 and R_2C_2; however, the performance ratio approaches unity for reasonable values of the circuit constants.

The effect of R_1C_1 and R_2C_2 upon the resolving time of the circuit must be taken into account in making a choice of circuit constants. In Fig. 14 contours are plotted which show the time required for a noise pulse to decay to e^{-3}, or 5 per cent of its maximum value. This is a more complete decay than is necessary as an indication of resolving time, but its choice simplifies computations from (6). Comparison of Figs. 13 and 14 shows that in the likely working range the best resolving time on each performance ratio contour occurs at $R_1C_2 = R_2C_2$. Considering only such values and keeping in mind that a short resolving time is preferable, we see that with these circuit time constants increased only to the value of the phosphorescent decay constant τ, the performance ratio is about 75 per cent; the inherent ratio of charge in a signal pulse to charge in a dark current pulse is brought out three-fourths as well as would be possible if the resolving time were increased to infinity. Since further improvements in the performance ratio cannot be large, and since they entail disproportionately large increases in resolving time, optimal values of the circuit constants would appear to be approximately $R_1C_1 = R_2C_2 = \tau$. As will be seen, however, the final choice of constants may be varied somewhat according to the conditions and requirements of the application.

Fluorescent Screen Decay Constant

Since the time constants of the circuit following the multiplier tube do not have to be set with high accuracy, an approximate value for the phosphorescent decay constant of the fluorescent screen will suffice. Satisfactory measurements can be made by direct study of the signal pulses on an oscilloscope, according to any of several circuit arrangements. Even with radiations characterized by weak signal pulses, the wide distribution of pulse amplitudes assures the occurrence of occasional pulses comprising a sufficient number of photoelectrons to permit estimation of the decay rate. When the yield of photoelectrons per signal pulse is very large, the decay curve of the phosphor, representing light intensity as a function of time during a signal pulse, may be directly observed on an oscilloscope having the necessary short resolving time. Since the curve observed on the oscilloscope represents merely the interaction of the desired decay curve on

the circuits which follow the multiplier tube, it is essential that the resolving time of all parts of the circuit be kept short in comparison to the decay time of the phosphor or that appropriate corrections be introduced. Thus, in a circuit like that shown in Fig. 11, R_1C_1 and R_2C_2 must be small. With this method of observation, the sweep may be triggered by the signal pulse itself. Successive signal pulses then appear at approximately the same starting position along the time axis. Though they vary statistically in amplitude, they form an umbrella of curves, the lower edge of which tends to be sharply defined by pulses having just enough amplitude to trigger the sweep, these being the pulses which occur with greatest frequency. Good visual measurements can be made, or the umbrella may be photographed with a simple time exposure. With a more elaborate photographic arrangement for registering high writing speeds, individual pulse traces may be photographed, the shutter time being adjusted to admit on the average only a few pulses.

With weak signal pulses, the method of the last paragraph is less suitable. Each signal pulse is composed of only a few component photoelectron pulses, which vary statistically in amplitude and position. The trace partially resolves these and appears very irregular in shape. The trace may be smoothed somewhat by using an R_1C_1 circuit constant which is not a great deal smaller than the decay constant of the phosphor, but the effect of this circuit constant on the apparent decay curve must be taken into account. Such an increase of R_1C_1 also increases the rise time, the result being that several of the few available photoelectrons are used up in the initial rise before the decay process begins to register. For weak pulses, therefore, the component photoelectrons are more economically utilized and the results are perhaps less questionable if one goes to the other extreme of introducing a very large multiplier-anode circuit constant R_1C_1, R_2C_2 still being kept small, so as to obtain an oscilloscopic trace similar to the response illustrated in Fig. 10(c). Under these conditions the resolving time for the rise is essentially instantaneous, and all the information inherent in the original signal pulse tends to be preserved. For a very large R_1C_1, the *slope* of the trace corresponds to the light intensity from the phosphor; except for an exponential decay, the curve does not strictly represent an inverted decay curve. Though the signal pulses may be used to trigger the oscilloscope sweep, no sharply defined envelope is formed, and accurate visual estimates are difficult.

Greater accuracy with weak signal pulses can be obtained by a logical extension of the method of the last paragraph, which requires, however, that individual traces be photographed. Though the method will be illustrated by the oscillographic recording of Fig. 12, which involved rapid motion by the film, a satisfactory oscillogram could have been obtained with the film at rest and with the exposure limited by an appropriate shutter time to one or two self-triggered signal pulses. From the oscillogram, the time of occurrence of each component photoelectron pulse in the signal pulse is first tabulated. A new curve is then drawn which is like the original one, except that all photoelectron pulses are plotted as steps of identical amplitude and the effect of the R_1C_1 capacitor discharge is omitted. A curve derived in this way from Fig. 12 is shown in Fig. 15. On still another curve the actual decay of the phosphor is plotted as in Fig. 16, the ordinates being slopes taken from the curve of Fig. 15; these slopes are proportional to the instantaneous light intensity or rate of occurrence of photoelectron pulses. The primary improvement of this method arises from the elimination of statistical variation in amplitudes of the photoelectron pulses comprising the signal pulse, the variation in this factor being much greater than that in the time-distribution of the photoelectron pulses. The method also eliminates all dependence upon circuit constants.

In Fig. 16 a curve for Patterson Type-D screen from a separate experiment is included for comparison, this curve having been obtained with microsecond-pulsed 30 kv X rays.[14] On the basis of these closely agreeing curves, the circuit time constants R_1C_1 and R_2C_2 in the final detector should be set at about 17 microseconds for this phosphor. Though the nonexponential decay drops to e^{-1} of the initial intensity in about 10 microseconds, the e^{-2} point is at about 35 microseconds, and the e^{-3} point is at about 100 microseconds. Thus the 17-microsecond circuit constant choice corresponds somewhat arbitrarily to the decay constant measured through the e^{-2} point; performance studies suggest that larger circuit constants would be better at low counting rates. This choice is primarily appropriate only to the detection of low-amplitude signal pulses, such as are characteristic of X rays, beta rays, and gamma rays. For alpha rays in fast-counting applications, considerably shorter circuit constants could be used.

For a phosphor having a nonexponential decay, the decay curve depends upon the type of excitation. This is easily observed when large signal pulses from alpha particles are compared with weak signal pulses from beta particles. The decay time of the Patterson Type-D screen for pulses from Po^{210} alpha particles is observed to be about one-fourth that for P^{32} beta particles. The density of excitation with alpha particles is much higher than with beta rays, due to the short range of the alpha particles. The shorter alpha-pulse decay time may be simply the consequence of the nonexponential decay curve, the active centers being excited to a higher point on the decay curve where the slope or decay rate is higher. However, the sharp inflection of the decay curve taken with pulsed X rays[14] occurring before the 1-microsecond point, suggests the presence of two distinct fluorescent processes of different decay times. If this is so, the short decay time obtained with high-density alpha-particle excitation might be explained on the basis of saturation of the fluorescence having the longer decay time. Regardless of the decay mechanism involved, it is interesting to note that as an alpha pulse subsides to the level of a beta pulse, its curve may be observed to fall off at about the same rate as that of a beta pulse.

The close agreement of the two curves for beta rays and X rays in Fig. 16 is rather surprising in view of the nonexponential nature of the decay. Two different types of radiation are involved, in one case X ray

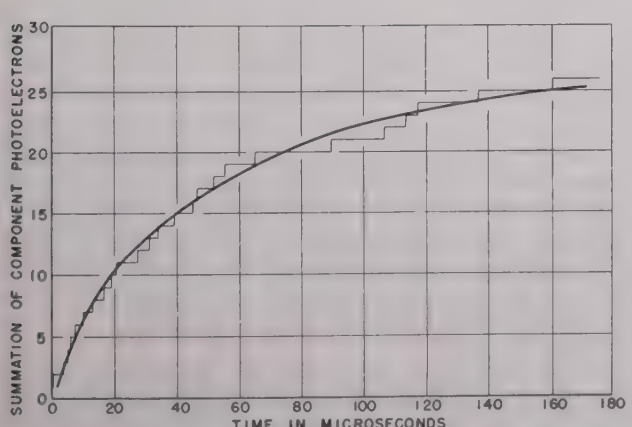

Fig. 15—Curve of integrated response for a beta-ray signal pulse, replotted from the large pulse in the oscillogram of Fig. 12.

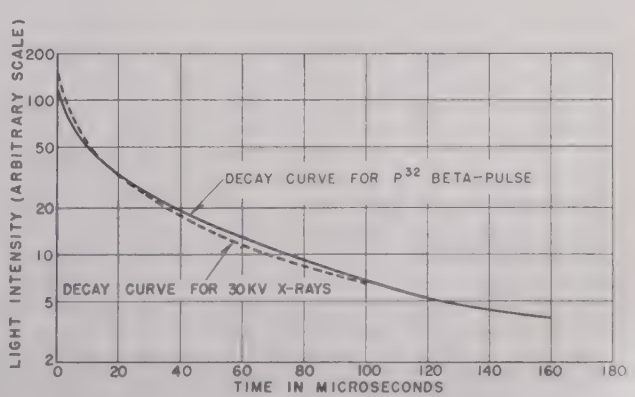

Fig. 16—Phosphorescent decay curves of zinc-sulfide (Patterson "D" X-ray screen) with excitation; (a) by a single beta particle, and (b) by microsecond irradiation with 30-kv X rays.

quanta having energies up to 30 kev, and in the other case a beta particle with an energy which can be as high as 1.7 Mev. Further, the excitation time might be expected to be different; a microsecond interval of "continuous" irradiation was used with the X rays, as compared with the essentially instantaneous excitation of the single beta particle. However, the excitation level is not necessarily different in the two cases. From estimates in the X-ray case of the number of phosphor particles in the screen and the number of X-ray quanta absorbed by the screen during each irradiation interval, it is found that the average number of X-ray quanta absorbed per phosphor crystal was considerably less than one; it is unlikely that any crystal received excitation from more than one quantum during a single observation interval. This is also obviously true for the beta-ray case, where a single event was observed. It is also known that excitation is not, in general, transmitted from one excited crystal to its neighbors. Thus, in each case, the level of excitation would appear to depend largely on the energy imparted to the screen by a single quantum or particle. Calculation of the energy lost by a beta particle in traversing the screen shows that it loses only about 30 kev, which is roughly the energy supplied by an X-ray quantum. One concludes that the actual excitation conditions for the two cases are quite similar, despite what appear at first glance to be very different conditions.

Several measurements of the decay time of phosphors suitable for photomultipliers have been published. Hofstadter reports a decay constant of $\frac{1}{2}$ microsecond for NaI(Tl). $CaWO_4$ is known[14] to have an exponential decay with a time constant of 6 microseconds, and $BaSO_4$–$PbSO_4$ a decay time of 0.6 microsecond. Wouters[15] has estimated the decay constant of anthracene as being in the neighborhood of 0.05 microsecond, though a more sensitive determination by Collins[16] gives a value of $1.3\pm0.2\times10^{-8}$ seconds. Collins also reports decay constants for naphthalene ($5.7\pm0.5\times10^{-8}$ seconds (and phenanthrene ($0.9\pm0.2\times10^{-8}$ seconds).

In the general field of phosphorescence many fundamental problems remain which have not yet been satisfactorily attacked. The methods discussed in this section may offer an additional experimental approach by which the mechanism of phosphorescence can be studied. Aside from techniques for studying ultra-short phosphorescent events, a chief merit of these methods is that measurements may be made upon individual quantum events.

Preamplifier Circuits

The output signal from the photomultiplier circuit is in the form of a charge, which produces a corresponding voltage on the capacitance of the anode circuit. The anode resistor serves merely to return this capacitor voltage to zero, and if the signal pulse duration is short compared to the time constant of this circuit, the peak anode voltage is independent of the resistance, and depends only on the charge and the capacitance. It is thus advantageous to keep the capacitance of the anode circuit small and constant in value. For this reason it is preferable to use a preamplifier head to which the photomultiplier tube is directly connected. The anode-circuit capacitance is then the grid capacitance of the first preamplifier tube, the anode capacitance of the multiplier itself, and the strays due to sockets and wiring. Compact construction will result in a total capacitance of about 10 $\mu\mu$f. The anode resistance is then chosen to give the required resolving time.

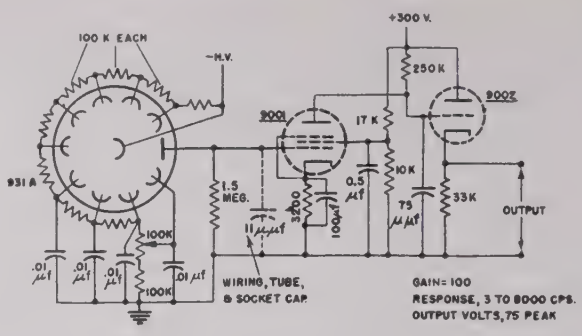

Fig. 17—The preamplifier circuit diagram.

A practical preamplifier circuit is shown in Fig. 17. This circuit was designed in accordance with the principles outlined under the section on circuit considerations for use with a ZnS:Ag phosphor which has a relatively long (17-microsecond) decay time. For use with other phosphors the photomultiplier anode resistor and the 75-$\mu\mu$f interstage filter capacitor should be modified to keep the corresponding RC time constants close to the decay time of the phosphors.

The power supply for the circuit is not shown, for it will vary in form according to the requirements of stability, compactness, and portability. A negative voltage of 700 to 1,000 volts is required for the dynode potential divider. It should preferably be variable over this range, since photomultiplier tubes show wide variations in gain and noise characteristics. The divider shown provides equal voltage steps for the various dynodes, although Wouters[15] has shown that greatly increased over-all gain can be obtained by running the later stages at higher voltages, without affecting the signal-to-noise ratio. It is likely that individual tubes behave differently in this respect, and it is probably necessary to adjust the voltage distribution for each tube used. The power supply need not be highly filtered, but, since the gain varies rapidly with dynode voltage, and the pulse-height distribution curves are quite steep, a certain amount of stabilization is desirable. A simple stabilizing device which is adequate for most purposes consists of a series of small neon tubes connected across the high-voltage supply, with a suitable series resistor to limit the current to a few milliamperes.

The 0.01-$\mu\mu$f capacitors across the bleeder at each of the last four dynode stages of the multiplier tube may be necessary to handle very large instantaneous currents during large signal pulses. A gain control in the last dynode stage is also provided to permit lowering of the amplification so as not to overload the 9001 pentode amplifier tube when large pulses are being observed. The latter part of the circuit in Fig. 17 comprises a direct-coupled cathode follower stage to drive at low impedance the cable leading to the discriminator and counting circuits. The output to the cable is positive and is of the order of 40 volts for beta pulses, which is adequate for precise operation of biased discriminators. The entire circuit may be built in a small box on the top of which the multiplier phototube detector may be mounted in an exposed position.

Discussion of discriminator, scaling, and counting circuits is outside the scope of this paper. These circuits are in general similar to those used with pulse ionization chambers, proportional counters, and Geiger counters, except that extremely fast circuits are necessary if full advantage of the high resolving power of the scintillation counter is to be realized.

Coincidence techniques, using two photomultipliers with a single phosphor, have been used[6,17] to obtain a considerable improvement in discrimination of signal over noise pulses.

Performance

The scintillation counter is, as yet, in the earlier stages of its development. Of the rather sizeable number of publications so far released, only one[18] describes the use of such a counter for an actual experiment in nuclear physics; all the rest are concerned with reports of its characteristics using various materials as phosphors under a wide variety of experimental conditions. From these reports it is possible to formulate a general picture of the performance of the tube, but as yet each experimenter who plans an application for the counter will be obliged to determine for himself the performance of the particular arrangement chosen.

[15] Louis F. Wouters, "Pulse characteristics of anthracene scintillation counters," *Phys. Rev.*, vol. 74, pp. 489–490; August 15, 1948.

[16] George B. Collins, "Decay times of scintillations," *Phys. Rev.*, vol. 74, pp. 1543–1544; November 15, 1948.

[17] Martin Deutsch, "High efficiency, high-speed scintillation counters for beta and gamma rays," (abstract), *Phys. Rev.*, vol. 73, p. 1240; May 15, 1948.

[18] S. DeBennedetti, F. R. McGowan, and J. E. Francis, Jr., "Self-delayed coincidences with scintillation counters," *Phys. Rev.*, vol. 73, pp. 1404–1405; June 1, 1948.

The efficiency of detection and the ability to detect small amounts of radiation are important characteristics of the detector. These are determined partly by the absorbing power and light yield of the phosphor, but are also affected in practice by the extent to which signal pulses and noise pulses overlap in amplitude. For this reason, the pulse height distribution curves constitute important information as to the behavior of the counter.

When the counting rate is measured as a function of discriminator bias voltage, integral-bias curves such as those shown in Fig. 18(a) are obtained. In this figure a curve for background noise is included along with curves for two radiation intensities differing by a factor of 10; for the two signal-pulse curves the background counting rate has been subtracted before plotting. The bias-voltage scale will vary with over-all amplification in the multiplier and later amplifiers. The distribution of pulse heights is shown in Fig. 18(b), in which the slopes of the curves in Fig. 18(a) are plotted.

When a thin zinc-sulfide phosphor is used, no upper limit to the counting rate is ordinarily observed as the bias voltage is reduced toward zero, either in the bias integral curve or in the pulse-amplitude distribution curve. This is especially surprising with signal pulses, for which a finite limit must logically exist. At low radiation intensities, the signal curves cannot be traced back close to zero bias because the signal-pulse rate is soon masked by the rapid increase in noise-pulse rate. Yet, even at high radiation intensities, the signal-pulse rate for X rays, gamma rays, or beta rays appears to rise indefinitely as zero bias is approached. In the case of signal, this continued rise near zero bias does not appear to represent a true increase in pulse rate. It is caused by multiple counting of statistical fluctuations near the end of signal pulses and of late photoelectrons associated with long-period, low-intensity phosphorescence of the fluorescent screen. The dashed branches of the signal curves in Fig. 18 are believed to represent the true pulse rates at low bias.

The most striking feature of the curves in Fig. 18 is the extremely broad distribution of pulse amplitudes. As far as evidence from a routine data set is concerned, the curves for signal pulses and noise pulses are similar to hyperbolas in that they appear to extend indefinitely in both directions. Even if the portion of the signal curves below 4 volts bias that is believed to be spurious is disregarded, the distribution is very broad. As the radiation intensity is lowered, complete discrimination of signal pulses against noise pulses becomes impractical with this phosphor. Complete discrimination can be approximated only by raising the bias until a large proportion of signal pulses are also rejected, thus reducing the efficiency with which the signal quanta are detected. The difficulty is greatly increased if a tube having a poor signal-to-noise ratio is used, or if any other factor in the construction of the detector acts so as to expand the noise curve to the right in relation to the signal curves.

Since curves such as these do not intersect the axes at well-defined points, it is often not possible to make satisfactory comparisons of average heights of pulses of various types from curves as ordinarily taken. The difficulty is the lack of a zero-bias intercept. Another aspect of this difficulty is illustrated by the signal-pulse curves for different radiation intensities in Fig. 18. It is seen that the general *upward* shift associated with an increase in radiation intensity is readily confused with an *outward* shift; that is, with an apparent increase in pulse amplitude. Without a knowledge as to where the termini of the curves lie, very little information as to relative pulse heights may be obtained. This effect is also very pronounced with visual observation on an oscilloscope. The eye sets artificial termini to the distribution curve, ignoring very large pulses because of their infrequency and very low ones because of their small size. Though the average height may seem fairly well defined, the impression of increasing pulse heights is very strong as the intensity of the radiation is increased. Thus visual estimates of relative pulse heights are in general to be mistrusted.

The broad distribution of noise-pulse amplitudes arises from statistical variation in gain per stage in the multiplier, and from the fact that noise pulses may originate from any of the stages of the multiplier. Not only do pulses vary a great deal in amplitude for thermal electrons emitted from the photocathode, but they overlap pulses from thermal electrons emitted from the first dynode, which overlap in turn pulses from later dynodes. Thus, it is quite reasonable for the noise pulse rate to increase continuously all the way to zero bias. Of course, only noise pulses originating at the photocathode receive full amplification and are of primary importance.

For signal pulses the spread in amplitudes is similarly contributed to by statistical variations in amplification per stage, although for large signal pulses this factor is reduced by the larger number of electrons initially ejected from the photocathode. More important is the variation in position in the phosphor of the exciting event. While certain geometries with easily stopped particles may permit rather definite localization of the fluorescence, gamma or X rays may generate only a very few secondary electrons at widely scattered points. Some of the secondaries may escape from the phosphor before imparting much of their energy. The light produced in various locations will be collected with different efficiencies by the photocathode. If a relatively small number of photoelectrons is produced at that cathode, there will be of course a spread expected in this number. Upon these factors are superimposed variations in light produced by different energy particles when nonmonchromatic radiation is used. In this connection it should be remarked that, if the phosphor is thin, the light produced by penetrating particles tends to be *inversely* proportional to their energy.

Although a considerable spread in signal pulse amplitude is thus to be expected, it is not reasonable for the distribution curve to rise indefinitely as zero bias is approached. For one thing, there should be no signal pulses smaller than the range associated with individual first-electrode photoelec-

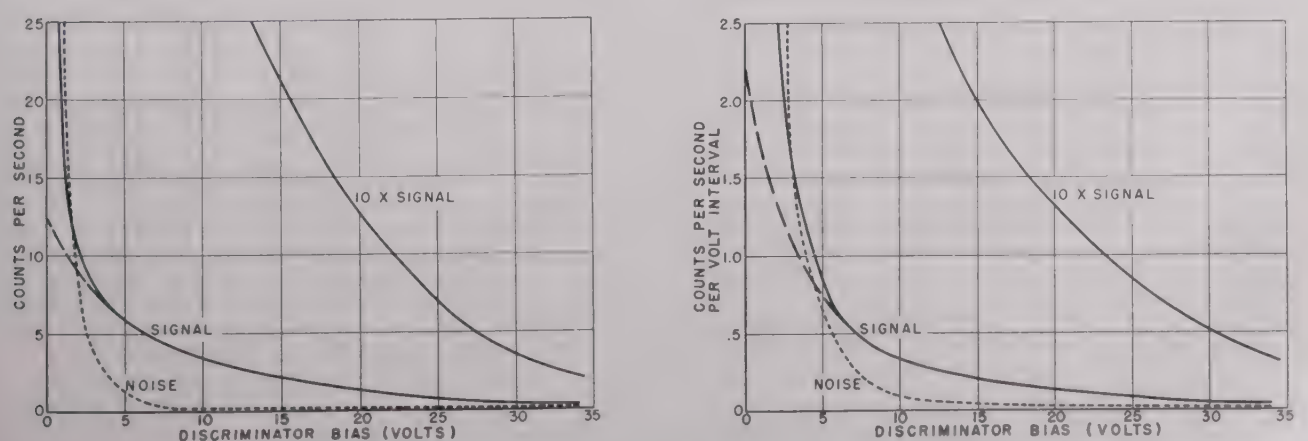

Fig. 18—(a) Sample integral bias curves, and (b) the corresponding pulse-height distribution curves.

trons. It has been definitely established that, in the case of the ZnS:Ag phosphor, this rise is due to multiple counting at low bias settings. The reason for this is apparent from oscillograms of the pulses. The individual photoelectron pulses which make up a signal pulse vary statistically in amplitude and position along the time axis. These component pulses are poorly integrated near the end of the signal pulse, where the average interval between photoelectrons begins to be an appreciable fraction of the time constant of the circuit. Thus, as the main pulse ends, the trace often bobs up and down one or more times. After this, there is an additional sprinkling of individual electrons which can sometimes be followed on the film with a degree of certainty for a millisecond or so. These photoelectrons are mostly late arrivals associated with the long period, low intensity phosphorescent persistence of the fluorescent screen. Thus multiple counting appears to arise in two ways; from poor integration at the end of the main pulse, and from late photoelectrons caused by long persistence in the phosphor.

Though ZnS is peculiar among the important phosphors in having a long period phosphorescence, multiple counting has also been observed with $CaWO_4$, which has an exponential decay. This is apparently entirely due to poor integration at the end of the main pulse. Such multiple counting is of course inherent in the nature of the detector; if resolving times are pushed close to the decay time of the phosphor, a certain amount of multiple counting will ensue. Multiple counting has also been observed to some extent with naphthalene and anthracene, even though these phosphors have apparently very short decay times.

It is evident from the above that under many conditions efficiency measurements are difficult to carry out with accuracy. With the localized fluorescence and very large pulse sizes obtained from alpha particles, the efficiency can be quite accurately measured; with less readily absorbed radiations which give smaller pulses, the count obtained will depend very much on the bias setting, and as this setting is reduced in an attempt to count smaller and smaller pulses, multiple counting may vitiate the results.

It appears in general, however, that the efficiency of the device is high. Deutsch[17] reports that, using naphthalene, substantially every electron is counted if it spends 0.15 Mev in the screen, when the tube is used at room temperature. At dry ice temperatures the minimum energy expenditure for which counting is highly efficient is reduced to 0.05 Mev. He also finds an efficiency of 20 per cent for 1.2 Mev gamma radiation, using naphthalene screens several centimeters thick. Most experimenters find that efficiencies are near 100 per cent for radiation which is effectively absorbed in the phosphor. Fast neutrons may be detected from the recoil protons produced in anthracene with an estimated efficiency of 10 per cent for one arrangement.[7] Using a zinc-sulfide phosphor substantially 100 per cent efficiency is obtained for 8 kev X rays.[3] All of these measurements are rough, but indicate that with care very good efficiencies can be obtained for a wide variety of types of radiation.

Comparison With Other Detectors

Under certain conditions the ionization chamber, the Geiger counter, the proportional counter, and the photomultiplier radiation detector may each approximate perfect efficiency of quantum detection, responding to all the information available in the incident radiation quanta. One may compare these detectors by considering the ease with which these conditions are obtained, the range of practical operation over which they apply, and the secondary characteristics which make one detector or another specially suited for certain applications.

In comparison with conventional detectors, the photomultiplier detector differs chiefly in that the primary detecting area may be quite small, but the absorption is relatively high. On the one hand, this restricts the new detector to narrow-beam applications if full sensitivity is to be realized. On the other hand, the small area of the fluorescent screen is an advantage in narrow-beam applications. It results in a greatly reduced sensitivity to general background radiation; the contribution of background radiation to the response of the new detector being so slight that it may be disregarded in most considerations. In its place, of course, one must consider the entirely different type of background arising from dark-current noise.

The new detector can hardly be compared with the ionization chamber, for the special advantages of the two instruments are entirely different. The ionization chamber tends to be much less stable and much more difficult to operate at its highest sensitivity. The photomultiplier detector, like the Geiger counter, is quite easily operated at full sensitivity. With the present phosphors the new detector does not share with the ionization chamber those fundamental properties which, according to the design of the chamber, permit measurements linearly related either to the absorbed radiation energy or to the roentgen units of incident radiation, over a wide range of radiation quantum energies. However, it is likely that linear dependence upon absorbed energy can be obtained with greater attention to the phosphor.

The photomultiplier detector is more easily compared with the proportional counter. Both detectors are capable of very high counting rates. There is a further similarity in that the pulse amplitude in the new detector tends to be dependent upon the type of radiation and the particle or quantum energy of the radiation. It is evident that the new detector may be used to discriminate between signal pulses which differ considerably in amplitude. The dependence of amplitude upon the energy of the radiation particle has not been investigated carefully. Other things being equal, the spread of pulse heights for particles of identical energy might be expected to be greater for the new detector than for the proportional counter. Perhaps cases peculiarly suited to discrimination by one detector or the other will be found. For high energy particles, however, complete absorption should be approximated better in the solid fluorescent screen than in the gas of the proportional counter. The photomultiplier detector tends to be more stable, more free of stray pickup, and less voltage sensitive than the proportional counter. Because of this the new detector would appear to be preferable for many applications not requiring strict proportionality of pulse amplitude to particle energy.

In many ways the photomultiplier detector is more nearly similar to the Geiger counter than any other conventional detector. Though technically limited by the decay time of the phosphor, the counting rate of the new detector effectively has almost no upper limit, inasmuch as integrated dc current measurements may be used with very high intensities. The speed with which measurements of a given accuracy can be completed with the new detector tends to be determined only by the available radiation intensity, rather than by an arbitrary upper limit of counting rate as in the Geiger counter. In addition to the ability to handle large amounts of radiation, the detector has an extremely high resolution which is determined by the decay characteristics of the phosphor. With certain phosphors, events separated by as little as 0.1 microsecond may be distinguished. The life time of the photomultiplier detector is much longer than that of a fast self-quenching Geiger counter, and the working characteristics appear to vary somewhat less from week to week. For penetrating radiations, the efficiency of the scintillation counter is superior to that of the Geiger counter, and for very soft radiations the absence of any window which might interfere with the measurement is a distinct advantage.

Perhaps the most promising feature of the new detector is the fact that the radiation is absorbed in a solid. Many of the coming advances in nuclear physics will arise from the study of the behavior of extremely energetic particles to be produced by the huge accelerators now being built. Since these particles are highly penetrating, the absorbing properties of the scintillation counter will place it at a considerable advantage with respect to other types of detectors. Thus one may expect to see a rapid development of this counter, together with a considerable widening of its field of application, in the near future.

A Standard Diode for Electron-Tube Oxide-Coated Cathode-Core-Material Approval Tests*

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Summary—A diode has been designed and used for testing various samples of cathode material in several plants and laboratories during recent years. Several criteria have been used for evaluating the emissive power of the various materials tested. To simulate the usual space-charge-limited emission test commonly used on receiving tubes, a cathode-temperature versus emission characteristic has been taken on each test lot. Temperature-limited emission has been examined under both low-field, low-temperature conditions and normal-temperature, high-field conditions. Results indicate that this method has several important advantages over the present approved method.

I. Introduction

THE ROLE played by the core material in the emission of electrons from oxide-coated nickel base cathodes has been the subject of considerable conjecture and controversy almost since the discovery of the oxide-coated cathode. Various hypotheses have been proposed from time to time to account for the apparent superiority of one core material over another. These hypotheses were not always in complete agreement, and attempts to resolve their differences frequently led to inconclusive results. The main difficulty seems to be in the complexity of the emission phenomena. Emission from oxide-coated cathodes is subject to time changes and fatigue effects, and to a very pronounced degree is dependent upon the composition, method of application, and processing of the materials used in the tube assembly. So far, it has been very difficult to isolate the single variable of core material for comprehensive studies.

Despite the fact that the mechanism of emission is not clearly understood, tube manufacturers have been producing, for many years, good oxide-coated-cathode tubes at relatively low cost. However, the possibility that a low-emission epidemic may suddenly shut down his production lines has caused every tube manufacturer to spend considerable time and money trying to immunize his product from all known carriers of this disease. Since the source of emission is the cathode, the material from which it is made obviously is one of the first places to look for trouble. For this reason, it has been standard practice for many years in radio-tube plants to check the performance of each new melt of nickel cathode material on one or more production tube types before accepting it for production use.

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In the past, the type of tube chosen for such tests, the conditions under which the test was made, the acceptance criteria, and the interpretation of test results has varied widely from company to company, and even from division to division of the same company. Since it was obviously impossible for a company to test each new melt of nickel on all production tube types under all conceivable operating conditions, most manufacturers tested two or three tube types as representative of various classes of tube service, such as rectifiers, oscillators, and power-output types. Sample quantities of each new cathode-nickel melt in a tubing size to fit these types would be ordered with the fervent hope that the type chosen would be in production when the samples arrived. In the happy but infrequent event that all test results, both initial and life-test performance on the various types run for approval, indicated that the new melt was inferior to, equal to, or superior to the comparison melt, the course of action presented no problem. In the more usual case, when test results disagreed, it was sometimes necessary to resort to occult practices to effect a decision. It is not particularly surprising, therefore, that new melts of core material accepted by one company or division would be rejected by another.

Nickel for seamless-cathode electron-tube use is produced in melts of about 10,000 pounds. Prior to World War II, usage of cathode nickel in the electron-tube industry was such that it was possible for a cathode supplier to hold a melt of this size for the period of approximately three months required to obtain melt approval from the various tube manufacturers. However, this situation was at best only tolerable, as it involved some financial risk on the part of the cathode supplier. If all companies should reject the melt, its value depreciated to that of Commercial Grade A material, this loss being sustained by the cathode supplier, who would then channel this material into less critical usage. If some companies accepted and some rejected the melt (the normal situation), the cathode supplier would purchase another melt to submit to the companies rejecting the first melt, and so on until all companies were satisfied. This method required considerable juggling of melts on the part of the vendor, who assumed the risk of supplying the proper-size cathode cylinder of the approved melt to each customer.

By 1944, the usage of seamless cathode material had reached a new high, and, in addition, new applications for tubing, particularly in the aircraft industries, placed an added drain on the cathode vendor and the raw material supplier. It became increasingly difficult to supply

each radio tube manufacturer with the particular nickel melt which met his melt approval requirements.

In January, 1945, a meeting was called by one of the cathode base material vendors to discuss this problem. Representatives of all cathode-tubing vendors and users were invited. It was the consensus of this group that the problem could best be studied through the medium of four committees, whose membership would be drawn from the various companies represented at this meeting. One committee was to propose referee methods for the chemical analysis and sampling of nickel melts. A second committee was to outline metallurgical test methods and a program for metallurgical development. A third committee was to prepare a specification for a standardized diode test to serve as a starting point for a laboratory test method. The fourth and last committee was to propose methods for presenting data on the multitube production test method of melt approval. These four committees were organized and later incorporated as Section A, Committee B4, Subcommittee VIII of the American Society for Testing Materials. This paper is a report on the work of the Diode Committee.

II. The Standard-Diode Approval-Test Method

The primary purpose of the diode structure, as conceived by the committee members, was to provide a standard tool for the investigation of the various cathode-material melts supplied for production use. It was felt that by providing a single structure which could be run conveniently in every tube plant, many of the variables introduced by the previously mentioned multitube tests could be eliminated. A secondary purpose of the diode was to investigate the effect of variations in the additives in the nickel melt and variations in processing and testing methods. In deference to the primary purpose of the diode, that of melt approval, it was agreed that the structure should consist of standard receiving-tube parts, so that standard receiving-tube equipment and techniques could be employed in processing them, thus insuring that a melt accepted for production use on the basis of diode tests would have been tested under conditions prevalent in the factory in which the melt would be used. It was realized that a structure utilizing receiving-tube parts and techniques might limit the effectiveness of the diode as a sensitive instrument for the investigation of melt additives and process variations.

Fig. 1—Structure of the standard diode designed by the Diode Committee.

The structure designed by the Diode Committee is shown in Fig. 1. Table I lists the important tube dimensions. The heater is designed for 6.3-volt, 300-ma operation. Under these conditions, the cathode operating temperature is approximately 1050°K. The anode was designed with an oval barrel to permit the use of a grid, should the occasion arise.

TABLE I

Standard Diode—Construction Details

Anode	
Material	0.005 inch Grade A Nickel
Dimensions	Inside diameter oval cross section: 0.132 ×0.185 inches Barrel length: 0.75 inches
Cathode Cylinder	
Material	Electronic Grade A seamless nickel tubing
Dimensions	Outside diameter: 0.045 inch Length: 1.06 inches
Cathode Coating	
Material	ASTM barium-strontium double-coprecipitated carbonates
Dimensions	Coated length: 0.475 inch (centrally located on cylinder) Coating weight: 3.40 ±0.4 milligrams
Stem	
Material	Lead glass (G12) Nickel-dumet-copper welds
Getter	
Material	Barium-cored iron wire
Heater	
Material	Cleaned and straightened tungsten wire
Dimensions	Wire weight: 12.0 milligrams ±1½ per cent per 200 mm Wire cut length: 7.05 ±0.04 inch
Form	Six-leg folded
Insulation Coating	Alundum
Bulb	Lime glass; T9
Base	Standard octal
Spacers	Mica 0.011 ±0.001 inch thick

The diode melt-testing method has several advantages over the multitube test method. It is a simple structure, easily produced on equipment available in all tube plants. Standard parts have been made available to all companies interested in diode testing, so that, regardless of where the tube is produced, uniformity of

parts is assured. It is necessary for the cathode-material vendor to produce only one size of cathode cylinder for melt-approval use if all testing is done on the diode. A comparison melt has been set aside for diodes which provides a uniform standard of comparison. Standardization of design, processing techniques, test methods and controls are possible, and changes found to improve the accuracy or reliability of the test method by one laboratory can be applied readily in other laboratories.

The general procedure used in conducting melt-approval tests on the diode is as follows: Test lots, as a rule, are run in groups consisting of at least ten "control" diodes employing the standard control-melt cathodes (Melt 66), and at least ten each of diodes employing cathodes of the melt or melts under test. All parts other than cathodes are obtained from a common inventory. Identical parts-processing and tube-processing schedules are used on all lots within the group. In general, these processes are standardized for a particular plant; i.e., all diode-test lots in one plant are processed under the same schedules. Some of these processes have been proposed as industry-wide diode standards by the Chemical Committee; e.g., parts cleaning, cathode-coating preparation, and certain testing schedules. Each plant has been allowed to set its own exhaust and aging schedules, because the approval of melts on the basis of diode tests implies the acceptance of the melt for production use, and the tube manufacturer is most interested in knowing how the melt will perform under his particular plant conditions.

III. Testing of the Standard Diode

To evaluate the emissive power of a cathode, it was assumed by the Diode Committee that some method of observing its total emission current (not limited by space charge) was necessary. If one attempts to test the diode structure, or any receiving-tube structure, for total or temperature-limited emission current, at its normal cathode temperature under static conditions, the rated wattage dissipation of the anode is usually exceeded long before temperature-limited current is drawn. Anode overheating usually results in gas evolution and subsequent cathode poisoning.

To avoid this difficulty, tubes may be tested for total emission by reducing the cathode temperature so that the temperature-limited current drawn does not exceed the rated anode dissipation. With this in mind, the Diode Committee fixed the anode potential for emission test at 40 volts, which, at normal cathode temperature, would give a space-charge-limited emission current in the neighborhood of 50 ma in the diode structure. This corresponds to a current density of about 120 ma per square centimeter, which is somewhat higher than is required by conventional emission tests on receiving-tube types. The full cathode-temperature versus emission-current curve at this fixed 40-volt anode potential was then taken on each tube under test and the position of the "knee" of the curve (that is, the transition point between temperature-limited emission and space-charge-limited emission) was taken as a measure of the relative emission capabilities of the cathode. Fig. 2 shows this curve on a normal tube and on a tube deficient in emissive power. It will be noted that, at rated cathode temperature, both tubes have the same space-charge-limited emission, but that on tube B the temperature-limited emission is somewhat lower than on tube A.

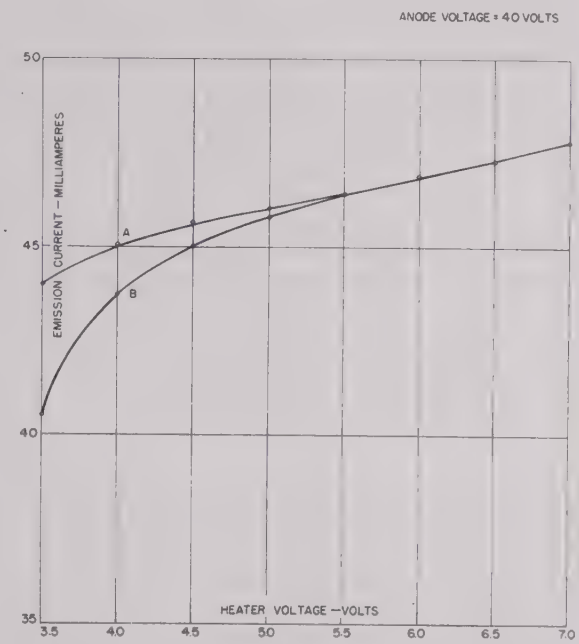

Fig. 2—Emission-current versus heater-voltage characteristic, American Society for Tetsing materials standard diode.

It was this sort of data that the Diode Committee set out to obtain on each new melt of cathode nickel submitted for test. Practically all conclusions reached to date in this program are based on cathode performance under this type of test. However, it was found that this cathode-temperature versus emission test has at least one serious limitation; the emission currents observed under these conditions at very low cathode temperatures were apt to be unstable. This may be due to the relatively high anode potential used on the test. It is well known that certain oxides and chlorides, which are on the surface of the anode as a result of the cleaning and processing of the tube parts and structure, tend to break down when the anode voltage exceeds about 4.5 volts. Oxygen or chlorine are released, and may poison the cathode surface. This effect should be particularly noticeable at low cathode temperatures, where the rate of barium production within the cathode is low. If the rate of poisoning exceeds the rate of barium production, slumping emission will result.

To avoid this difficulty, data have recently been taken under low field conditions, with an anode potential of 4.0 volts, which should be safely below the breakdown

voltage of the oxides and chlorides likely to be found on the anode surface. To obtain temperature-limited emission at this low anode voltage on the diode, it was necessary to lower the heater input voltage to 1.75 volts, which corresponds to a cathode temperature of about 640°K. Emission currents obtained under these conditions are relatively stable.

During the late war, there was considerable interest in the pulse-emission properties of cathodes, and, since many receiving tube types were being used in pulsed applications, the Diode Committee thought it desirable to examine new cathode melts for their pulsed-emission properties. Peak emissions as of high as 100 amperes per square centimeter were reported on nickel-base cathodes by observers at the MIT Radiation Laboratory,[1] the Bartol Foundation,[2] and elsewhere. The pulsed-emission testing techniques developed by these laboratories were borrowed and utilized for diode pulse testing by one of the companies involved in the diode program. The pulse technique has one significant advantage over the two static emission tests mentioned previously, in that it permits examination of temperature-limited emission at rated cathode temperatures without exceeding the rated anode dissipation of the diode.

Life Tests

The electron-tube manufacturer is interested not only in the initial performance of a cathode melt, but also in the performance against time under operating conditions. The Diode Committee has incorporated a life test as part of the melt approval procedure. The conditions of this test have been modified as data were accumulated under various drain conditions. The present life test schedule consists of a minimum of 500 hours operation at rated heater voltage ($Ef = 6.3$ volts) and a drain of approximately 100 ma per square centimeter.

IV. Diode-Test Results

From the time of its inception, the Diode Committee has been conducting diode tests of three general classes:

1. Tests directed toward improving the structure and standardizing processing and testing procedures
2. Melt-approval tests on commercial cathode nickel
3. Tests directed toward examining the effects of variations in chemical composition of the cathode nickel.

Tests in the first class have been and are being conducted in considerable volume. Results from this class of tests are the basis for the formulation of diode structure and process specifications.

Melt-approval tests are represented in the summary in Table II, by the compilation of test results on commercial melts 70 through 76.

[1] E. A. Coomes, "Pulsed properties of oxide cathodes," *Jour. Appl. Phys.*, vol. 17, pp. 647–654; August, 1946.
[2] M. A. Pomerantz, "Magnetron cathodes," Proc. I.R.E., vol. 34, pp. 903–910; November, 1946.

Melt-composition tests have been conducted on about fifty different nickel-base materials. Test results on only a few of these lots are shown in Table II, for comparison with the 220-alloy commercial melts. The test results reported here represent only a very small portion of the total diode tests run during the three-year period of diode investigation, but serve to illustrate the effectiveness of this structure in differentiating between the emission capabilities of cathodes as a function of core material. The data reported are based solely on the information obtained from the 40-volt static characteristic curves (see Section III). Low-field-emission test, pulsed-emission test, and life-test results are not included in this report, because these data are still incomplete. Since it is difficult to characterize the 40-volt static characteristic test data by a complete heater-voltage versus emission-current curve, a "figure of merit" rating based on the difference in slope of these curves in the region between heater 4.5 and 6.5 volts has been substituted. This "figure of merit" was determined in the following manner:

$$\text{F.M.} = \left[\frac{Is_{6.5} - Is_{4.5}}{2}\right]_{\text{control}} - \left[\frac{Is_{6.5} - Is_{4.5}}{2}\right]_{\text{test}}$$

where

$Is_{6.5}$ = emission current with 6.5 volts applied to heater

$Is_{4.5}$ = emission current with 4.5 volts applied to heater.

Thus, for example, a "figure of merit" of −0.5 for melt 70 (Company "2") indicates that the slope of the Ef versus I_s curve for the average of the ten tubes made with melt 70 cathode material was 0.5 ma/volt steeper in the region between 4.5 and 6.5 volts heater voltage than its control lot (melt 66).

V. Discussion of Diode Test Results

The seven melts, 70 through 76, whose "figure of merit" ratings are given in Table II, are 220-alloy seamless tubing material submitted to the radio tube indus-

TABLE II

Summary of Initial Test Results on Diode Tests of Commercial Cathode Material Melts Seamless Tubing

"Normal" 220-alloy material figure-of-merit rating

Melt Number	Company "1"	Company "2"	Company "3"	Company "4"	Company "5"	Company "6"	Test Description
70		−0.5	−2.1	−0.3	+0.7		
71		−1.8	−1.0 −1.9	−1.9	+0.1		Initial sample
71C		+0.1	−0.2				Initial sample cleaned
71R	+0.5	−0.1	+0.1	−0.3	+0.5		Second sample, melt 71
72	−0.4	−0.4	−0.2		−0.1	−0.4	
73	−0.8	−0.1	−0.2		−0.1	−0.2	
74	−0.5	−0.3	−0.4		−0.1	+0.5	
75	−0.5	−0.2	−0.5		0	−0.1	
76	−0.2	0	+0.4		+0.1	−0.3	
Lockseam Tubing							
W	− 9.6	− 7.5	−15.9				"Passive" material, 499 alloy
K	−10.0	−11.4	−15.4				"Passive" material, 707 alloy
X	− 0.2	+ 0.1	− 1.3				"Active" material, 599 alloy
M	− 0.4	0	− 1.3				"Active" material, 766 alloy

try for approval testing. Most of the data obtained by the Diode Committee so far has been on this alloy, although approval tests have also been conducted on other alloys in lockseam tubing. For comparative purposes, "figures of merit" are shown in Table II for the three grades of cathode tubing commonly employed by the receiving-tube industry. These three grades are termed "normal," "active," and "passive" alloy base materials by the ASTM.[3] This classification refers to the relative barium-producing potential of the alloy, as determined by the percentage of reducing agent present in the melt. "Active" alloys contain a relatively high percentage of reducing agents, such as silicon and magnesium; "passive" alloys contain relatively low percentages of reducing agents; and "normal" alloys contain a moderate amount of reducing agents. Typical chemical analyses of these three grades of material are listed in Table III.

TABLE III

Typical Chemical Compositions of "Normal," "Active" and "Passive" Cathode Base Materials†

	"Normal"	"Active"	"Passive"
Carbon	0.15%*	0.12%*	0.10%*
Copper	0.20	0.04	0.04
Iron	0.20	0.05–0.01	0.05
Magnesium	0.01–0.1	0.0 –0.15	0
Manganese	0.20	0.10	0.02
Sulphur	0.008	0.005	0.005
Silicon	0.01–0.05	0.15–0.25	0.01
Nickel and Cobalt	99.0 min.	Balance	Balance

† All figures are percentages by weights. Compositions are maxima unless a range is indicated.

* Carbon content is generally lower as wall thickness is reduced through successive annealings. At 0.0022 inch wall, carbon is 0.02 per cent nominal, while at 0.005 inch wall, carbon may exceed 0.05 per cent nominal.

Certain minor constituents may be found in varying amounts according to melting practice for the alloys. Such elements may be aluminum, titanium, boron, etc.

The differences observed in "figure-of-merit" ratings for melts 70 through 76 as reported by the six companies reporting diode-test results were considered by the diode committee to be random variations within the sensitivity of the test method, with one exception, the initial sample of melt 71. It was felt that some significance could be attached to the fact that three of the four companies reporting diode results on this melt found it somewhat inferior to the control melt 66. Company "3" repeated the test on their initial sample, and again found it poor. Investigation showed that the three companies reporting poor results on the initial sample had obtained their melt-approval samples from one run of cathode tubing, while the company reporting good results, Company "5," on the initial sample had obtained its melt-approval sample from a later drawing of the material. Surface contamination of the initial sample was immediately suspected. Companies "2" and "3" therefore tried surface cleaning of their initial sample. The results of these tests, indicated as melt 71C on Table II, indicated that this suspicion might be well founded. Company "3" found a definite improvement in emission performance from the suspected melt after etching the bare sleeves. Company "2," employing a different cleaning procedure, found the performance of this suspected lot of tubing could be brought above that of the control melt by this means. The original sample processed along with this test uncleaned, was still very poor.

As a result of these findings, the cathode-tubing supplier prepared a new sample of melt 71, with special care being taken to avoid all possible contaminants in the drawing operations. These samples were submitted to the same companies who had reported on this melt previously. Results on this second sample are shown in Table II as melt 71R. All companies testing this sample found it better in emission performance than its control melt 66. To substantiate the conclusion that the initial sample of melt 71 was bad, two comparative tests were run later by Company "2" on a production tube type under normal factory conditions. In both cases, a high initial shrinkage due to poor emission was obtained on the initial sample, whereas normal results were obtained on the comparison melt run at the same time.

Results on a few melts of "active" and "passive" alloys are also tabulated on Table II. Melts W and K show the effect on emission of reduction in silicon and magnesium content of the base material. The "active" alloy tests X and M show performance characteristics very similar to the "normal" alloy tests. It should be borne in mind however, that these lots represent results on only single samples of these alloys, and should not be not be taken as necessarily representative of the average emission performance characteristics of these materials.

VI. Conclusions

An inventory of the results achieved in the three years of diode testing shows a very favorable balance. Correlation between test results reported by the various plants testing cathode-core-material melts has shown marked improvement with diode testing. The study of testing methods has brought about a better understanding of the effects of tube design and processing upon emission. This has resulted in improved tube-to-tube and test-to-test uniformity. Work on processing, testing, and materials standards has been started, and in most cases completed. The effects on emission of various additives in core materials, and the significance of modifications in core material melting, drawing, and cleaning methods has been evaluated. In some cases, the cause of poor activity in a particular test sample has been isolated.

Full understanding of the emission problem still seems remote. However, because active interest in the problem has been aroused and crystallized into a joint effort, the immediate goal, that of a satisfactory melt-approval test method, now seems attainable.

[3] A specification covering Radio Tube Core Material classifications is now being prepared by Section A, Committee B4, Subcommittee 8, ASTM.

Testing Cathode Materials in Factory Production*

J. T. ACKER†

Summary—**The paper deals with the methods of testing radio-tube cathode materials in factor production, and especially with a comparison of several specific lots of materials of variable content. It is believed that this is the first time the electron-tube industry has made mass tests on a well-controlled engineering basis of cathode materials which vary in singe component elements.**

THE CHAOTIC conditions under which the manufacturers of electron tubes have been testing cathode-nickel tubing for their use have been described by McCormack.[1] These costly tests, together with prove-in tests on other components of electron tubes, such as alkaline-earth carbonates, getters, and anodes, are performed to insure good manufacturing yields. The lack of fundamental knowledge concerning thermionic emission makes these acceptance tests necessary.

Each company in the industry accepts or rejects a new melt on the basis of the final test results and life performance of electron tubes containing cathodes made from the new melt, as compared with tubes being currently made using cathodes from the previously accepted melt. The type of tube used for this comparison is usually one of those in current production. The results of these tests, as reported by the entire industry to the suppliers of cathode tubing, were contradictory and full of inconsistencies. Through one of the supplier's efforts, a meeting of the representatives of the tube manufacturers was called in January, 1945, to discuss the situation and try to formulate better methods of evaluating cathode nickel tubing. A section of Subcommittee VIII of Committee B4 of the American Society for Testing Materials, was formed for this purpose, and possibly to improve the understanding of thermionic-emission phenomena and the type of nickel used.

The intent of this paper is to report on the progress made by the so-called "Data Subsection" in co-ordinating the methods of test and interpretation of results so that an industry-wide evaluation of each melt may be made to compare with evaluations based on the use of simple and much cheaper diode structures and ultimately chemical and/or metallurgical tests on the nickel.

One of the first steps taken to reduce the factory prove-in tests to a common denominator was to establish a standard melt of cathode nickel against which all tube manufacturers would rate new melts. One of the major suppliers of cathode tubing agreed to set aside for this purpose a 200-pound portion of melt 66, which is a 220-grade nickel melt of typical composition and normal 10,000-pound size, and which had given apparently normal test results in electron tubes. This quantity of material is sufficient to last for many years for melt-approval control purposes exclusively. Sample cathodes of appropriate size from this melt are sent along with the same size cathodes from a new melt to each factory when a new melt is to be tested for approval. The prove-in factory runs are made on cathodes from the new melt and melt 66 simultaneously and under identical processing conditions.

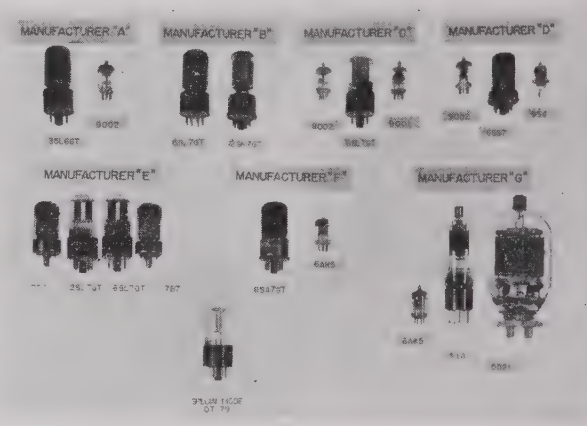

Fig. 1—Variety of electron tubes formerly used in cathode testing.

A second step in the direction of greater uniformity of test conditions was to strive to have the participating companies choose similar types of tubes for prove-in factory runs. It had been the practice to use any type of tube that happened to be in production at the time of the melt-approval test. The accompanying Fig. 1 shows the great variety of types of tubes formerly used by the industry for this purpose. Fig. 2 shows the pentodes that are currently used in these tests.

The committee found that the industry was evaluating the melts on the basis of initial shrinkage, initial tube characteristics, and life-performance tests. A study was made of the early test results in order to formulate a pattern or form that could be used by each company in reporting its test results, regardless of the parameters, for purposes of evaluation.

Factory prove-in runs of 50 to 200 tubes each are made using cathodes from the test melt and the standard melt 66. Variations in geometry and processing are

* Decimal classification: R720. Original manuscript received by the Institute, May 25, 1948. Presented, 1948 IRE National Convention, March 24, 1948, New York, N. Y.

† Western Electric Company, Allentown, Pa.

[1] R. L. McCormack, "A standard diode for electron-tube oxide-coated cathode-core-material approval tests," PROC. I.R.E., this issue, pp. 683–687.

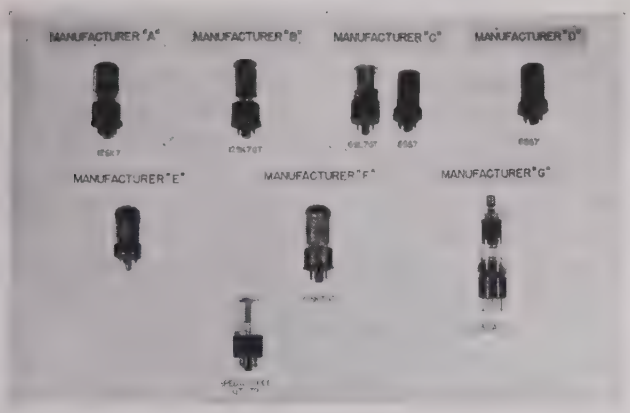

Fig. 2—Electron tubes used in recent cathode testing.

minimized by simultaneous manufacture under shop conditions. The shrinkage is counted only for causes related to the cathode. The initial tube characteristics are taken either on all of the tubes or on a representative sample of the run. Life tests are carried out for 500 hours on 5 to 10 tubes selected at random from the lots. In each category the comparison is expressed as a ratio of results for the test melt to the control melt. In order to avoid zero values in the shrinkage ratios, the per cent yield rather than the per cent shrinkage is used. It has been agreed that shrinkage and life are more important than initial characteristics, so that, in arriving at the over-all figure of merit, they are rated as twice as important. The sum of all the ratios so adjusted gives the over-all figure of merit for the industry. Figs. 3, 4, and 5 show the results obtained by eight plants, on melts 72 to 76 inclusive, when compared with melt 66. Melt 72 is a normal 220-grade melt of seamless tubing, while melts 73 to 76, inclusive, were made from a single 10,000-

INITIAL CHARACTERISTIC DATA

MELT NO.	MANUFACTURER A	B	C		D	E	F	G	POINT TOTAL
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7gt	311A	
	AV. OF Gm IO TUBES	AV. Is ÷ AV. Gm OF 8 TUBES. FIG USED HERE IS AV OF AV Is AND AV. Gm	72-74: AV Gm OF 20 TUBES	75: AV. Gm OF IO TUBES	72-74: AV. Gm AT 3.5 Ef OF IO TUBES 75,76 AV Gm OF 32 TUBES AND IO TUBES RESP.	72,74,76: AV. Gm OF 8 TUBES 73,75 AV. Is OF 8 TUBES	72-76 AV Gm OF 5 TUBES	AV Gm ÷ AV. Is OF IO TUBES 72-576 FIG. USED HERE IS AV OF AV. Gm ÷ AV Is	AV Gm OF 72-44 TUBES 73-47 " 74-51 " 75-33 " 76-35 "	NOT WEIGHTED
72	1.03	0.998	0.985	0.97	1.026	1.02	0.963	0.986	7.979
73	1.01	1.085	1.01	0.98	0.819	0.93	0.972	0.994	7.800
74	1.03	1.038	1.05	0.94	1.013	0.96	0.942	0.969	7.962
75	1.00	1.009	0.988	0.97	0.900	1.00	1.02	0.996	7.883
76	0.99	1.051	0.966	1.00	0.953	0.99	1.005	0.978	7.933

Fig. 4—Factory prove-in tests on cathode nickel melts.

pound melt of nickel, half of which was poured normally with additional silicon added to the second half before pouring. Each half was split between seamless and weldrawn tubing as shown in Table I.

TABLE I

	Normal Half—0.02 per cent Si	*Special Half—0.09 per cent Si*
Seamless	Melt 73	Melt 74
Weldrawn	Melt 75	Melt 76

It will be noted from Fig. 5 that the over-all figure of merit would be 40 for a melt of identical test results with melt 66. The spread of these five melts is not very large—only 2.9 per cent. This is not surprising, in view of the fact that these melts are all essentially identical with the exception of the variation in silicon content.

INITIAL SHRINKAGE DATA

MELT NO.	MANUFACTURER A	B	C		D	E	F	G	POINT TOTAL
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7	311A	
	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	66,72-74 RUN AS UNIT 66,75,76 RUN AS UNIT	WEIGHTED BY FACTOR OF 2
72	1.00	1.02	1.00	1.00	1.092	1.00	1.00	0.812	16.048
73	1.00	0.95	1.00	1.00	1.110	1.00	0.90	0.962	15.886
74	1.00	1.046	0.949	0.91	1.092	0.96	0.93	0.949	15.838
75	1.00	1.019	0.994	0.96	1.00	0.96	1.00	1.046	15.950
76	1.00	1.020	1.03	1.00	1.00	0.98	1.00	0.817	15.694

Fig. 3—Factory prove-in tests on cathode nickel melts.

LIFE TEST DATA

MELT NO	MANUFACTURER A	B	C		D	E	F	G	POINT TOTAL	GRAND TOTAL
	12SK7gt	12SK7	6SL7gt	6SS7	6SS7	7B7	12SK7gt	311A		
	AV. Gm OF 5 TUBES 504 HR. LIFE	AV. Gm OF 5 TUBES 220 HR LIFE	AV. Gm OF IO TUBES 72-74 AT 500 HR LIFE	AV. Gm OF Ef OF 5 TUBES 72-74 AT AV Gm AT .63 Ef OF IO TUBES 75,76	AV. Gm OF 5 TUBES 500 HR LIFE	AV. Gm OF 5 TUBES 500 HR. LIFE	AV Gm OF 5 TUBES 500 HR. LIFE 72, 73,74 RATIO CALC AT 300 HR PT	AV Gm OF IO TUBES 1,000 HR. LIFE 75, 76 RATIO CALC AT 500 HR	WEIGHTED BY FACTOR OF 2	
72	1.09	1.005	1.11	1.06	0.975	1.03	1.00	1.013	16.486	40.534
73	1.01	0.973	1.163	1.04	0.961	1.07	1.008	1.008	16.502	40.138
74	1.02	0.970	1.11	1.04	0.989	0.989	0.824	1.005	15.870	39.670
75	1.02	0.980	1.08	1.13	1.012	1.04	0.998	0.997	16.472	40.309
76	0.99	0.939	1.07	1.120	1.022	0.960	0.967	0.979	16.126	39.753

Fig. 5—Factory prove-in tests on cathode nickel melts.

However, the individual variations in each melt among the various companies are still very large. The shrinkage results are +11.6 per cent and −18.3 per cent from the standard, the tube characteristics vary +8.5 per cent and −18.1 per cent from the standard, and the life results are +16.3 per cent and −17.6 per cent from the standard. There still are instances, as there were formerly, before this work started, where one company gets the best results for a given melt in a particular comparison, and another company finds it poorest. The maximum variations for a given melt are of the order of 25 per cent. Despite these difficulties, the over-all figure of merit seems to give a true picture of the quality of the cathode nickel. This is substantiated by the fact that the melt which shows up to be the worst was the only one of this series rejected by more than one company.

It is recognized that the cathode sleeve is, perhaps, of secondary importance to the coating applied to the cathode and the processing of the tube. That is why it is so important to keep these and other factors constant when making cathode-nickel tests. In the course of the work it has been found also that surface contamination of the cathode sleeve may mask the effect of the base-metal composition on thermionic emission.

It is felt that this work has put melt-approval tests on at least a semiquantitative basis, and that a melt substantially different from the usual variety will show a figure of merit higher or lower by several per cent. An instruction manual for factory testing by this method is being prepared in considerable detail so that even better control of factory tests will be made in the future, and the results are expected to be more reliable.

A Method of Measurement of the Internal Series Resistance of a Capacitor Under Surge Conditions*

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Summary—**Recent application of capacitors as energy-storage devices for low-impedance loads, such as short-duration light sources and electric detonators, has emphasized the importance of examination of capacitor efficiency from this standpoint. Ballistic measurements, using a vacuum thermocouple and galvanometer, are shown to afford the desired evaluation.**

Theory

RECENT APPLICATION of capacitors to spark photography, radar, and the firing of low-resistance electric detonators has involved their use as energy-storage devices in connection with circuits of very low impedance. Consequently, it becomes pertinent to inquire about the effectiveness of the capacitor in delivering its stored energy under these conditions.

Evaluation of the low internal series resistance in question, not readily made by the usual bridge methods, is important in application of the capacitor to some low-impedance surge circuit, as will be shown below.

The energy stored in a capacitor is

$$J = \frac{CE^2}{2}$$

where J is the work or energy in joules, C is the capacitance in farads, and E the potential in volts. It is convenient to discuss the percentage of this energy made available to the external load as a function of the load resistance and the internal series resistance of the capacitor. If we assume that the capacitor and load are represented by the simple circuit of Fig. 1, showing the capacitor

Fig. 1

of capacitance C, charged to a potential E and having an internal series resistance R_S, connected to a load resistance R_L, the expression for the energy transfer must be

$$J = \frac{CE^2}{2} = R_S \int_0^\infty i^2 dt + R_L \int_0^\infty i^2 dt. \qquad (1)$$

The first and second terms on the right-hand side of this expression represent the work converted into heat in the resistors R_S and R_L, which can be represented by J_S and J_L, respectively, so that

$$J = \tfrac{1}{2}CE^2 = J_S + J_L. \qquad (2)$$

As the energy in the series circuit divided proportionally to the resistances,

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$$\frac{J_S}{J_L} = \frac{R_S}{R_L}. \tag{3}$$

Then, combining (2) and (3),

$$J_L = \frac{J}{1 + \frac{R_S}{R_L}}. \tag{4}$$

Thus, the energy delivered to the load can be expressed as the fraction of the energy of the charged capacitor by evaluating the fraction

$$\frac{1}{1 + \frac{R_S}{R_L}}.$$

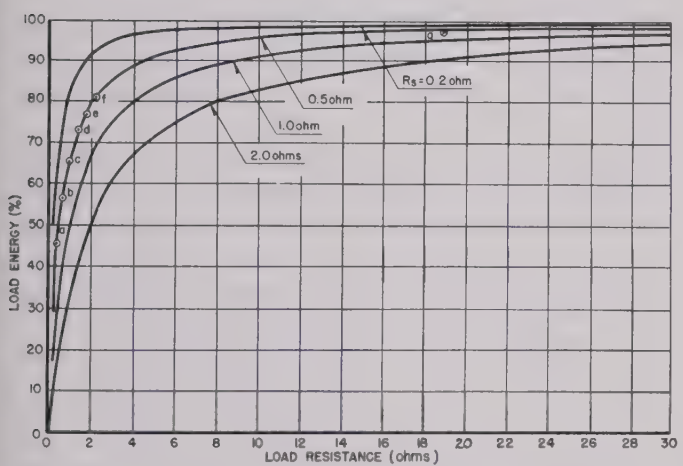

Fig. 2—Load energy versus load resistance, expressed as per cent of $\frac{1}{2}CE^2$ for several values of R_S.

Theoretical values have been obtained for capacitors whose internal series resistance R_S is 0.2 ohm, 0.5 ohm, 1.0 ohm, and 2.0 ohms, and the resulting theoretical curves are plotted in Fig. 2. Of these curves, the one for $R_S = 1.0$ ohm can be considered as basic, so that, if the load resistance R_L is expressed as a factor times R_S, the per cent of charge energy to the load can be derived.

Measurement of the internal series resistance can be made by varying the load resistance R_L over a range of values, noting the corresponding variation of energy delivered to the load, and fitting the values thus obtained to the nearest theoretical curve. However, since the equations so far introduced contain only first-order terms, the theoretical curves may be replaced by straight lines and the computations correspondingly simplified.

Rewriting (4) as

$$\frac{J}{J_L} = 1 + R_S \frac{1}{R_L} \tag{4'}$$

and plotting J/J_L against $1/R_L$ for various values of R_S, we obtain the straight solid lines of Fig. 3, which represent the same four cases shown by the curves of Fig. 2.

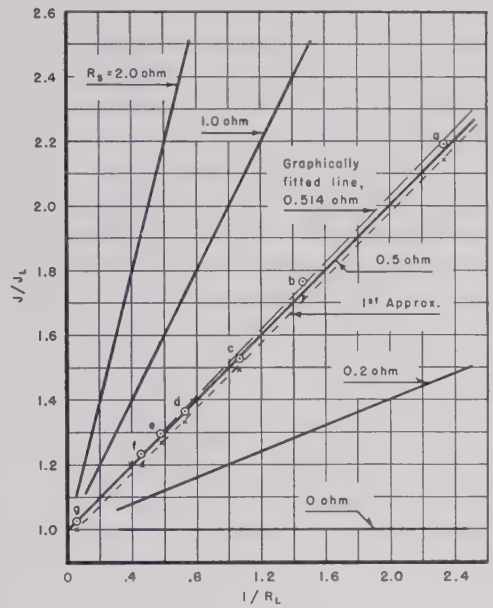

Fig. 3—J/J_L versus $1/R_L$ for several values of R_S.

Experimental Arrangement and Analysis of Reading Method

Since only total energies are involved in the foregoing analysis, some method of measurement of these energies is indicated, and it has been found that a simple ballistic method is satisfactory, provided adequate precautions are taken. Fig. 4 shows a circuit arrangement

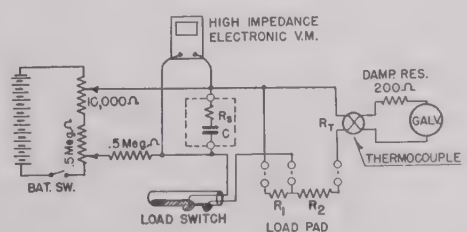

Fig. 4

which includes a small vacuum thermocouple and long-period galvanometer to measure the energy delivered to the load; a "load pad," which consists of a plug-in resistor combination; and a "load switch," whose function is to discharge the capacitor into the load when a galvanometer reading is to be taken. It is to be noted that the capacitor-charging circuit is of sufficiently high impedance so that no measurable current will be delivered directly from the battery to the thermocouple.

Resistors R_1 and R_2 of the load pad shown in the circuit, together with the heater resistance R_T of the

thermocouple, constitute the load resistance R_L previously discussed, the relationship being

$$\frac{1}{R_L} = \frac{R_1 + R_2 + R_T}{R_1(R_2 + R_T)} \tag{5}$$

where the reciprocal form is obtained for convenience in using the chart of Fig. 3.

In practice, because of the number of variables involved, it was found most convenient to proportion the values of R_1 and R_2 by setting up the experiment on a trial basis, reading galvanometer deflections as obtained from a 1-μf mica capacitor having a 1-ohm resistor connected in series. Resistance values were adjusted by trial until the galvanometer swings were of the same order. This precaution was taken to avoid errors due to nonlinearity of the thermocouple voltage with temperature. In order to translate the galvanometer scale reading into a value which can be used in conjunction with the curves of Fig. 2 or Fig. 3, it must be multiplied by a factor which expresses the ratio of the energy taken by the thermocouple heater to that of the entire load J_L. On the basis of instantaneous power and total energy considerations, it can be shown that

$$J_L = kD \frac{\left(1 + \frac{R_2}{R_T}\right)(R_1 + R_2 + R_T)}{R_1} \tag{6}$$

where D is the galvanometer deflection and k is some calibration constant which need not be evaluated in the practice of this method. For convenience, we can now call the fraction in (6) the "load energy factor," writing

$$\text{load energy factor} = \frac{\left(1 + \frac{R_2}{R_T}\right)(R_1 + R_2 + R_T)}{R_1}.$$

Computational Procedure

The computations are divided into two parts. The first of these covers the factors determined by the values of the load pads, and need not be repeated for other capacitors unless other load pads are constructed. The second part of the procedure is performed quickly by using successive approximations.

Table I includes sample calculations made on a 0.12-μf General Electric Pyranol capacitor (Cat. 26F699) rated at 15,000 volts dc. The first six columns may be set up once and for all when the load pads have been constructed. The values of R_S sought for a particular capacitor are finally obtained in column 12, while the last column has been used here simply to record the "RC constant" as a means of indicating the rate of discharge or equivalent frequency components.

It has been seen that, when load pad g is used, nearly all of the energy goes to the external load. Therefore, if we set $J_L = J$ for this load, making J/J_L equal to unity, first approximation values of J/J_L can be obtained for the other pads, since these values are inversely proportional to the number of load energy units computed for each pad. Such first approximation values are shown in column 10 of Table I and have been plotted in Fig. 3, the dotted line being drawn to make the best fit possible.

Such a line will be seen to intercept the J/J_L axis at a point slightly less than unity, about 0.975 in this case. Since the intercept must be at unity, we now raise the left end of the line arbitrarily. This shows that the ordinate for load pad g should be increased to about 1.025. Using this corrected value of J/J_L for load pad g, we now recompute the values of J/J_L for the other load pads, obtaining column 11 as a second approximation. While it can be seen from the foregoing that a better estimate of the value of J/J_L for the high-resistance load pad g could have been made on the basis of expected values for R_S for commercial capacitors, it can also be seen that this assumption is not necessary, since one or two approximations at the most will give rapid convergence to an accurate answer.

The values of column 11 have been plotted as shown in Fig. 3, and the graphically fitted line, 0.514 ohm, is seen to intercept the J/J_L axis very close to unity. The values of R_S given in column 12 are computed from (4), rewritten for convenience as

TABLE I

Load-Pad Characteristics and Calculations from Experimental Readings Taken on a 0.12-μf Capacitor

Load-Pad Data						Experimental and Calculated Values						
1	2	3	4	5	6	7	8	9	10	11	12	13
Load Pad	R_1 (ohms)	R_2 (ohms)	R_T (ohms)	$1/R_L$ (ohms)	Load Energy Factor	E (volts)	Galv. Defl. (cm.)	Load Energy Units	J/J_L (first approx.)	J/J_L (second approx.)	R_S (ohms)	RC (micro-sec.)
g	∞	16.46	2.44	0.0529	7.75	150	2.89	22.4	1.00	1.025	(0.473)	2.33
f	3.76	2.77	2.44	0.458	5.09	150	3.65	18.60	1.20	1.233	0.509	0.32
e	2.96	1.79	2.44	0.575	4.21	150	4.21	17.70	1.27	1.296	0.515	0.27
d	2.28	1.00	2.44	0.729	3.54	150	4.76	16.84	1.33	1.364	0.500	0.22
c	1.42	0.31	2.44	1.068	3.31	150	4.54	15.04	1.49	1.526	0.492	0.17
b	0.953	0	2.44	1.46	3.56	150	3.65	13.00	1.72	1.766	0.524	0.15
a	0.519	0	2.44	2.34	5.70	150	1.84	10.48	2.14	2.190	0.508	0.11

$$R_S = \frac{\frac{J}{J_L} - 1}{1/R_L} . \qquad (4'')$$

From the graph of Fig. 3 it is seen that only two load pads are absolutely necessary. If low and high values of R_L are chosen, as obtained through load pads a and g, quite satisfactory measurements can be made to an adequate order of accuracy for subsequent calculations of energy deliverable by the capacitor to an external circuit.

Discussion

The most important single factor in successful application of this method of measurement is the use of a "perfect" switch for closing the circuit. This switch, shown as the "load switch" in Fig. 4, must close the circuit through the load in such a manner that no electrical energy will be expended in the switch during the closing process. In practice, this means that the contacts must neither spark nor bounce, that they must not be required to break down an oxide film upon closing, and that the entire switch circuit, including leads, must have, when closed, a resistance low in comparison to the resistance being measured.

A number of switches have been tried, and no solid-contact switch, including one of the vacuum type, has proved satisfactory. The most successful switches seem to be those of the mercury-to-mercury contact type, provided they are well made, with very clean mercury and clean metal electrodes dipping into the mercury.[1]

The galvanometer used in the measurements described was a Rubicon (Cat. No. 3412-S), having a resistance of 39 ohms and a current sensitivity of 0.01 microamperes per mm. This instrument has a period of 4.5 seconds, and was used at slightly less than critical damping. It should be realized that use of a galvanometer of higher sensitivity will impose less rigid requirements on the load switch, inasmuch as the required capacitor-charging potential is lowered.

The vacuum thermocouple used was a G.E. Type K A-91×536 with a heater element rated at 2.5 ohms (actually, 2.44 ohms). These thermocouples are available with heater elements having a resistance as low as 1 ohm (Type K A-91×537), and there would be some advantage in the use of the lower resistance value in delivering more energy to the galvanometer when measuring with the lower resistance loads.

[1] Switches which have been found satisfactory—all of the mercury-to-mercury contact type—include the Minneapolis-Honeywell Type H-168 "Con-Tac-Tor," the G.E. Code Nos. 4-24 KR1 and 40-40 KR1 "Kon-Nec-Tors," and a magnetically operated mercury-plunger relay now available commercially from the Champion Mfg. Co., 509 Fifth Ave., New York, N. Y.

It is, of course, advisable in these measurements to keep lead length down and to eliminate errors due to contact resistance. In this connection, it would be preferable to provide four connectors for the load pads instead of three, in order to avoid inclusion of one contact resistance in the common load and thermocouple circuit. However, no detectable error due to this common contact has been discovered in the method as presented here. A rough calculation has been made of the resistances of the leads involved in the capacitor-discharge circuit, on the basis of transients of 10^{-7} seconds, with the result that the total resistance is estimated to be in the neighborhood of 0.05 ohm or less.

Conclusion

The method of measurement here discussed seems to be the simplest approach to the problem in practice. It should be noted that, when factors such as dielectric hysteresis and polarization are considered, the circuit which is an accurate equivalent of a capacitor at all frequencies must have upwards of four branches, involving perhaps seven or more components of resistance and capacitance, and that any method of measurement which assumes simpler conditions should closely duplicate the conditions under which the capacitor will be used. Furthermore, it is generally difficult to measure very low values of resistance with measurement circuits of much higher resistance, such as would be involved with usual electron-tube devices. There are, of course, circuit arrangements by which some time constant might be evaluated, but no practical way is seen of devising the necessary low-impedance switching electronically.

Admittedly, there are involved here some implicit assumptions which may not be rigidly true. Variation of the load changes the discharge time, and probably thereby alters the path of current flow in the capacitor. Also, the internal losses in the dielectric may depend somewhat upon the discharge time. Nevertheless, the method closely parallels the use of the capacitor as an energy-storage device for low-impedance loads.

While it is realized that with this measurement method the charging voltage of the capacitor is quite low, it appears that there is no reason to expect a change in series-resistance characteristics of the capacitor at higher voltages.

Acknowledgment

The author wishes to express his thanks to C. N. Warfield for his thoughtful criticism and suggestion of the linear relationships, and to other members of the Staff of The Johns Hopkins University, Applied Physics Laboratory, for their aid in preparing these notes for publication.

Experimental Ultra-High-Frequency Multiplex Broadcasting System*

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Summary—A definite indication that the need for broadcast facilities in the near future will far exceed the available channels is recognized. A feasible expansion appears to be in the ultra-high-frequency spectrum.

To produce the maximum number of channels at ultra-high frequencies, a multiplex system of broadcasting has many advantages: A large number of broadcast programs are transmitted at an assigned frequency from a single location and using only one transmitter and antenna system. Effective use is thus made of an optimum transmitting site, a considerable advantage at very- and ultra-high frequencies where line-of-sight limitation of transmission exists.

An experimental eight-channel high-fidelity multiplex broadcasting system has been developed and operated during the past year. Multiplex operation is achieved by time-sharing pulse-time modulation. The operating frequency is 930 Mc.

The discussion includes a description and operating characteristics of the major components, including modulator, transmitter-antenna system, and receiver.

I. Introduction

EVEN WITH the opening of the new FM broadcast band, there is definite indication that the need for broadcast facilities will, in the not-distant future, far exceed the available channels. To relieve the situation, it seems safe to assume that further expansion of the broadcast spectrum will become necessary. Such further expansion appears feasible only at ultra-high frequencies, or beyond.

The development here reported was, therefore, directed to the determination of how broadcasting could best be achieved at ultra-high frequencies. The actual frequency used was 930 Mc, within the 920 to 940-Mc range assigned by the Federal Communications Commission for experimental broadcasting. The system developed, however, could be reproduced anywhere in the ultra- or even the super-high-frequency range.

It should be emphasized that this development is not intended to replace either the present AM or FM broadcasting facilities, but rather to supplement both when there is demand for more channels.

To produce the maximum number of useful broadcast channels at ultra-high frequencies, it appears more desirable and economical to broadcast in multiplex with a large number of channels per assigned frequency, rather than one frequency assignment per broadcast channel, as is conventional at lower frequencies. This, of course, does not reduce bandwidth requirements per channel, but it does reduce or eliminate wasteful "guard" frequency separation between adjacent stations to avoid the damaging effects of possible carrier drift. In addition, there is a more potent and fundamental reason for choosing a multiplex form of broadcasting at ultra-high frequencies, rather than the conventional simplex system used at lower frequencies. This has to do with the radiation and propagation characteristics of these waves.

At ultra-high frequencies, a relatively high antenna power gain (concentration of radiated energy in desired directions) is easily and economically achieved. Since propagation is essentially limited to line of sight, tall building tops and other elevated spots offer the best locations for transmitting antennas. In most localities, there are only one or two such effective transmitting sites, and each will accommodate about one transmitter. In a multiplex broadcasting system, a substantial number of transmissions share each optimum site. This advantage is even more pronounced from the receiving standpoint especially for television.

For each transmitting station, there are a multitude of receiving sites. At ultra-high frequencies, antenna gain can be obtained cheaply, even for reception. A very small and simple array, a dish, or a horn will provide a large amount of power gain and directivity. When, because of a large number of transmitting sites, the programs are received from many directions, a single highly directive receiving antenna is not useable unless fitted with an expensive steering mechanism. With a multiplex broadcasting system, the same receiving-antenna orientation not only will give optimum response on all channels but may be adjusted to reduce interfering signals and noise. These important factors provide substantial reasons for using a multiplex form of broadcasting in the ultra-high-frequency spectrum.

A multiplex system, for broadcasting as well as for telephony and general communication applications, may take many forms. Amplitude modulation of several mutually interrelated subcarriers, finally modulating the ultra-high-frequency carrier, would be one possibility. Frequency modulation of subcarriers, which in turn modulate the final carrier frequency, might also be used. Pulse systems involving amplitude, time, width, etc., modulation also are important possibilities. Various combinations of the above might offer even greater advantages than any single type of modulation.

In view of recent advances in pulse techniques and, particularly, since high-power pulse-type rf generators (magnetrons and some triodes) are available for most, or all, of the ultra-high-frequency band, a pulse system

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of modulation with a time-sharing form of multiplexing was agreed on for the first development of this system.[1]

II. Pulse-Time-Modulation Multiplex System

To demonstrate as effectively as possible the versatility and advantages of the system, it was decided to multiplex eight broadcast-quality channels. For each channel, 24,000 pulses per second are used to sample each program. This rate corresponds approximately to three times the highest af to be transmitted. In addition to the channel pulses, which are varied in timing to provide the necessary modulation for each channel, a fixed marker pulse is also transmitted at a 24-kc rate, one for each train of eight pulses corresponding to the eight channels. This marker pulse provides the necessary reference point for demodulation at the receiver.

Fig. 1 shows a block diagram of the experimental system recently completed and demonstrated. Each of the eight af signals is used to vary the timing of pulses approximately 0.5 microsecond wide. The resulting video-frequency signal is then used to pulse an rf oscillator, in much the same manner as in radar applications.

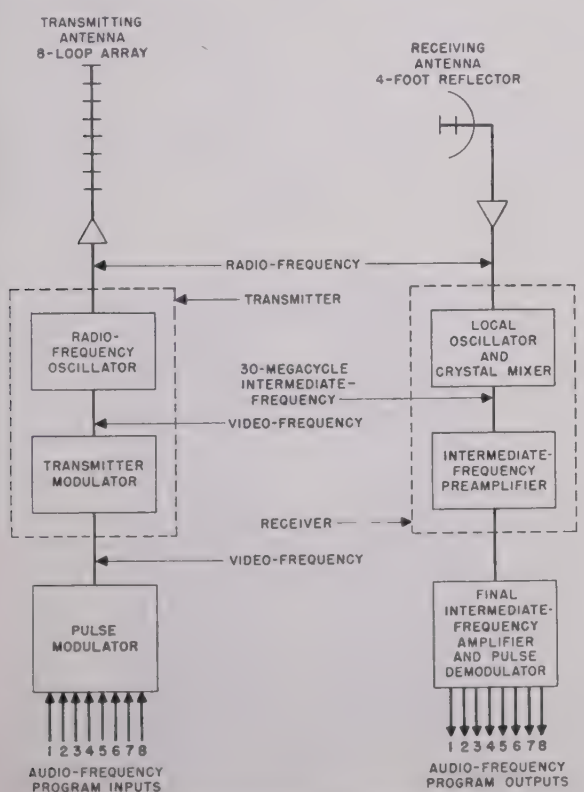

Fig. 1—Block diagram of the multiplex broadcasting system.

For reception, a conventional local oscillator and mixer produce the if signal voltage; this is amplified and detected to provide the video-frequency signal, which is then used to select channels and demodulate each program. Details of the various components making up the complete system are given in the following sections.

[1] D. D. Greig, "Multiplex broadcasting," *Elec. Commun.*, vol. 23, pp. 19–26; March, 1946.

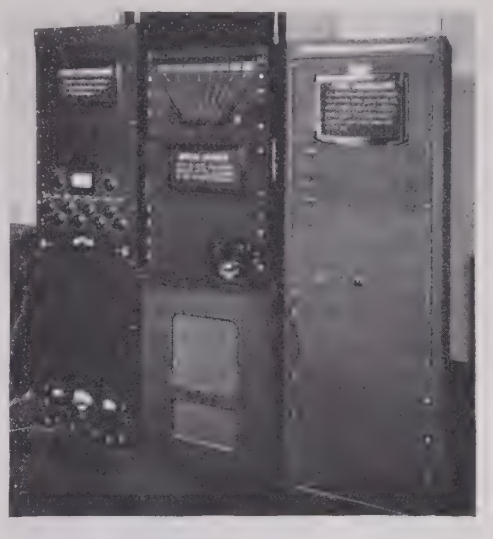

Fig. 2—Experimental multiplex broadcasting system, showing af control panel, pulse modulator, and monitor receiver.

The transmitting station during all tests on this system was located on the roof of 67 Broad Street, approximately 485 feet above ground in downtown New York City.

Fig. 2 shows a view of the experimental transmitter equipment exclusive of the transmitter modulator and rf generator; these were located close to the antenna. Fig. 3 shows the experimental omnidirectional transmitting antenna.

Most of the receiving tests were made at the Nutley Laboratories, 11 miles away, where the receiving antenna was located on a roof, approximately 25 feet above the surrounding terrain. Comparable receiving

Fig. 3—Omnidirectional eight-loop transmitting antenna for the experimental multiplex broadcasting system, located at 67 Broad St., New York, N. Y.

tests have also been made in the surrounding countryside with portable equipment installed in a station wagon.

Typical services carried simultaneously during various tests and demonstrations included rebroadcasting of standard AM and FM programs and operation of stock ticker (Dow Jones), teletype (Mackay Radio), facsimile (New York Times), and photo transmission. The receiver, shown in Fig. 4, is quite conventional in appearance. It differs in operation from more conventional

Fig. 4—Master receiving console.

receivers only in that no rf tuning is required. The channel selection is done entirely at video frequencies by timing circuits.

Where more than one program is desired simultaneously, for example, in separate rooms of the same building, it is not necessary to duplicate the complete receiver but only a portion of the video-frequency system and an af circuit for each service. These latter, called "satellite" receivers, are quite simple in construction but incapable of operation in the absence of the main receiving unit.

III. Pulse Modulator

The pulse modulator consists of the following four main sections: af amplifier-limiter, pulse generator and delay line, pulse-time-modulation units, and finally a section for mixing the eight channels and marker to form a complete train of time-division time-modulated pulses.

Programs from the eight different sources are supplied to the af amplifier-limiters for modulating purposes. These amplifiers, which are gain controlled, have a response within 1 db from 30 to 10,000 cps. For full modulation (± 1 microsecond), an input level of 0 db is required (1 mw in 600 ohms). The modulation excursions must be limited, however, so that any channel does not overmodulate and cause cross talk on any other channel by moving so far in timing that it appears in a position that might be held by an adjacent-channel pulse. To prevent this overmodulation, limiters are placed across the af input-transformer secondary. These consist of germanium crystals with a fixed bias voltage. The af output is then used to modulate a sawtooth wave obtained in proper sequence and delay from the pulse generator.

The pulse generator and delay line make up a single compact unit. The electron-coupled oscillator in this unit determines the base repetition rate of the pulse frequency per channel and is, therefore, designed for very stable operation. In this particular system, that rate is 24 kc. The sine-wave output is then shaped into a sawtooth having a 6-microsecond rise time, and this travels along the delay line from a cathode follower. This delay line is so designed that it will pass the sawtooth without deteriorating the slope and with minimum attenuation. Taps at every 4.63 microseconds are connected to cathode followers. Each cathode follower is connected by a short piece of coaxial cable to the modulator input. This now supplies each channel modulator with a wave form having proper delay, a linear rise time, and the required amplitude so that it may be operated on to obtain time modulation.

This is done by a circuit called the channel modulator.[2] As shown in Fig. 5, this unit takes a slice of the incoming sawtooth wave and converts it to a square pulse. By changing the bias on this double clipper at an af rate, a width-modulated pulse is obtained. Differentiating and using the leading edge produces a time-modulated pulse to be further shaped and processed. The channel

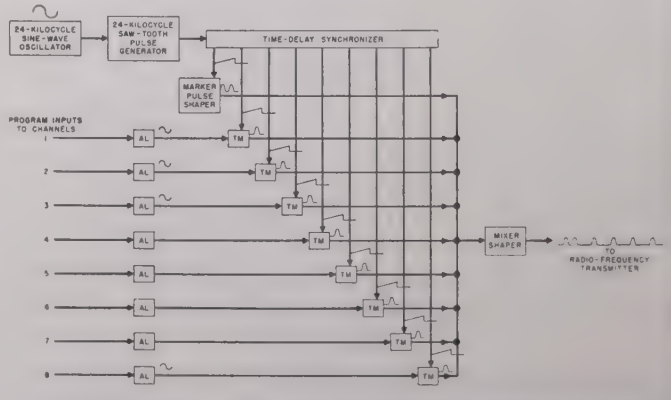

Fig. 5—Block diagram of the modulation system, showing conversion of af channels to mixed train of time-modulated pulses. *AL* are amplifier limiters, and *TM* are time modulators.

[2] D. D. Grieg and A. M. Levine, "Pulse-modulated multiplex radio relay system—terminal equipment," *Elec. Commun.*, vol. 23, pp. 159–178; June, 1946.

pulses are 0.5 microsecond wide at an amplitude 10 per cent above the base, and require 0.15 microsecond to build up to 0.9 or decay to 0.1 of maximum amplitude.

These channel pulses are clipped so that any amplitude modulation is removed, and they are then electronically mixed in such a manner that the pulse train is delivered from a cathode follower to a 70-ohm coaxial cable. Besides the channel pulses, a marker pulse is supplied to the mixer. This marker consists of two pulses, identical in shape to the channel pulses, but spaced only 1.3 microseconds apart. No other two pulses in the entire train, at even the remotest positions of modulation, ever come this close together. This then gives an identifying factor to the pulse train so that a selector device is able to distinguish the program channels. To produce such a double pulse, a single pulse is generated in an identical manner to the channel pulses and passed down an open-circuited delay line. This line has a delay of 0.65 microsecond, thus requiring 1.3 microseconds for the pulse to travel along the line, reflect at the open-circuited end, and return to the starting point. The resulting double pulse is mixed with the eight channel pulses, and the full train then goes to the transmitter modulator.

IV. Transmitter Equipment

The transmitter proper, shown in Fig. 6, consists essentially of two parts: the transmitter modulator and the rf oscillator, both mounted on a single 72-inch relay rack.

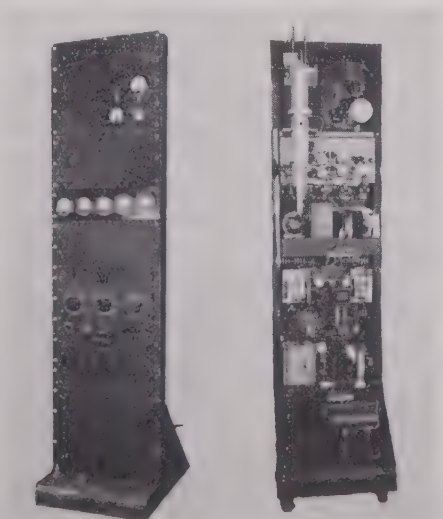

Fig. 6—Front and back view of the transmitter unit.

The transmitter modulator must amplify the low-amplitude pulse train coming from the pulse modulator and deliver signals at approximately 300 volts over a 50-ohm circuit to the grid of the oscillator. The output stage of the transmitter modulator employs two 807 tubes in parallel as cathode followers. The design follows that of a conventional video-frequency amplifier with the same precautions for linear phase shift and flat frequency response of both the low and high end of the video-frequency spectrum. In this particular case, 3 Mc was chosen as the highest frequency and 400 cps as the point where the low-frequency response was down 3 db. Both of these points were chosen for reasons of cross talk and maintenance of pulse characteristics for a signal-to-noise improvement[3] over AM of about 20 db. Because of the type of modulation, linearity of amplification is unimportant and the tubes may be operated for maximum efficiency.

In the experimental installation, it was convenient to locate the pulse-modulator unit (Fig. 2) several floors below the roof on which the transmitter and antenna were located. This necessitated a good resistive termination (accurate matching) of the cable carrying the pulse signals between the two units; any mismatch at this point would produce reflections that would travel back down the cable and cause objectionable cross talk.

For the rf generator, both triodes and magnetrons were considered. More power was possible with available magnetrons and, had the operating frequency been higher in the ultra-high-frequency range, a magnetron would have been chosen. However in the 1,000-Mc region, triode circuitry is simpler and more flexible for an initial experimental unit. A triode oscillator of the tuned-plate tuned-cathode variety using a type 2214B tube was, therefore, used. The circuit is shown schematically in Fig. 7. An adjustable grid "bell," fitting coaxially over the cathode line, provides the necessary feedback. Both plate and grid modulation are feasible, though the latter is somewhat simpler. The experimental unit produced a peak output of 500 watts or more, with an average power output not exceeding 50 watts.

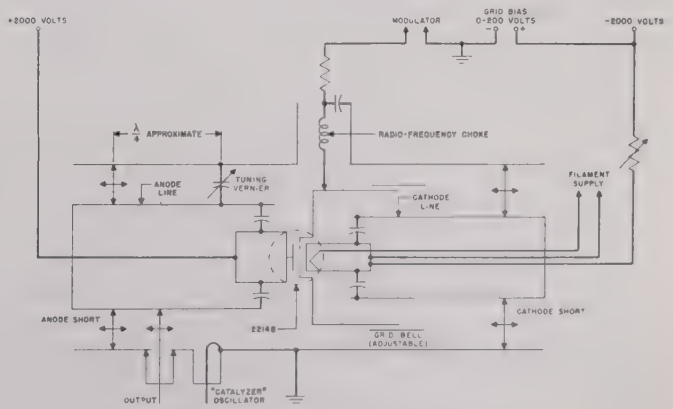

Fig. 7—Transmitter oscillator schematic.

An important consideration of transmitter design for this type of application is the question of frequency stability. An automatic-frequency-control system, to hold the center frequency stable with high precision, is feasible for both magnetron or triode oscillators. A crystal

[3] E. M. Deloraine and E. Labin, "Pulse time modulation," *Elec. Commun.*, vol. 22, n. 2, pp. 91–98; 1944.

frequency-control system with a series of multipliers to the final operating frequency, or more simply a master-oscillator power-amplifier combination, are also feasible through the 1,000-Mc region. In the present case, however, a frequency-stabilizing system did not appear to contribute sufficiently to the initial experimental tests to justify the additional equipment and complication.

Tests indicated that the inherent frequency instability, drift, etc., of the rf oscillator, described above, under all the various operating conditions did not exceed ± 0.4 Mc; this is quite tolerable since the total rf bandwidth is nearly 6 Mc. For any final equipment design of a multiplex broadcasting system, a frequency-stabilizing circuit could be readily incorporated.

In a pulse-time system of modulation, a very important consideration is the uniformity of the starting time of the individual oscillations each time the oscillator is pulsed. Experiments show that, even when the pulses are very accurately timed, there is likely to be a considerable random variation of this factor. The reason for this is, apparently, the fact that a random-noise signal of a certain minimum amplitude is necessary to initiate the rf oscillations when the dc pulse is applied to the tube. This random variation in timing of the pulses is only a small portion of 1 microsecond (which represents full modulation), but produces a noise signal that may be only 30 db below the full-modulation signal. By optimum adjustment of the oscillator feedback circuit, it is possible to minimize this source of noise. A more practical solution is to couple to the transmitter oscillator cavity the output of a small continuous-wave rf oscillator of a type normally used for receiver local oscillators. This auxiliary oscillator—called the catalyzer oscillator—provides sufficient signal level to insure a starting time of oscillations substantially independent of any random-noise variation. Experimentally, it was determined that the catalyzer oscillator frequency could deviate considerably from the pulsed-oscillator frequency without appreciable change in performance.

In addition to the above, the transmitter has the usual monitoring equipment, including an echo-box-type cavity for checking frequency and a reflectometer-detector to monitor rf power output as well as the standing-wave ratio on the output transmission line to the antenna. An rf detector coupled to this transmission line plus a pulse-time-modulation demodulator allows complete over-all monitoring of the programs on the eight separate channels.

V. Transmitting Antenna

As in the majority of broadcast applications, the radiated transmitter power must be omnidirectional in the horizontal plane to give uniform coverage within the broadcast service area. Also, in line with conventional practice, horizontal polarization was chosen. The basic radiator that provides omnidirectional horizontally polarized radiation is the horizontal loop antenna, used in a large number of applications in the very-high-frequency range, including aerial navigation and FM broadcasting.

To reinforce the radiation in the horizontal plane and reduce wasteful high- and low-angle radiation, a vertical stack of eight square loops (shown in Fig. 3) is used. This compresses the vertical radiation pattern to approximately 9° between the half-power points, and thus provides a power gain of approximately 8 compared to a half-wave dipole. Larger gain than this is feasible, and for a final design, a stack of 16 or more loops may be used.

The transmission-line problem is quite important in the 1,000-Mc region. Most reliable are standardized solid-dielectric cables. However their power-handling capacity is limited, and the amount of attenuation, if long lengths are to be used, is quite substantial. Available air-dielectric lines do not have these limitations, but have disadvantages of their own, namely: discontinuities due to beads and connectors. Furthermore, gassing or air-drying equipment is necessary to keep moisture out for operation over any period of time. Waveguides would perhaps be practical for a final installation, but were considered to be too bulky for an initial experimental setup. In the present case, only 30 feet of line was necessary and RG-17/U solid-dielectric cable was used. The attenuation is less than 1.5 db, which is quite tolerable. Solid-dielectric cable is also used for the feeders within the antenna array. The antenna and transmission-line system has given satisfactory operation under all weather conditions encountered during summer and winter.

VI. Receiving Equipment

The receiving equipment installation at Nutley consisted of antenna cable, one master receiver, and several satellite receivers to reproduce simultaneously at least four of the eight broadcast channels.

Since in a multiplex broadcasting system all programs originate from the same transmitting site, it is evident that a highly directive receiving antenna oriented along the direction of propagation may be used. This means not only a great increase in the signal strength received, but also a substantial decrease in interfering signals. In the ultra-high-frequency range, a great deal of directivity may be obtained quite economically. In the present case, a 4-foot dish with a simple dipole giving an antenna power gain of approximately 50 was used. A more compact, though less directive, horn antenna was used for portable reception in field

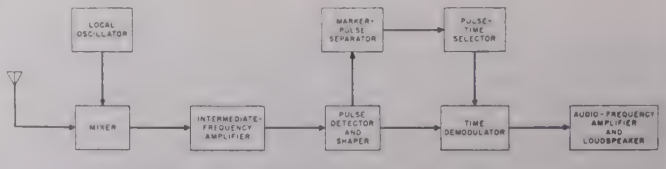

Fig. 8—Block diagram of the pulse-time-modulation receiver.

tests with a station wagon. Solid-dielectric RG-8/U cable connects the antenna to the master receiver.

An over-all block diagram of the complete receiver is shown in Fig. 8. The superheterodyne circuit uses a 2C40 local oscillator and a 1N28 crystal mixer with if output at 30 Mc. No tuning of any rf circuit is necessary for channel selection, because this is done entirely at video frequencies. A schematic of the local oscillator and mixer circuit is shown in Fig. 9. No rf amplification is used since, at these frequencies, the crystal-mixer input circuit provides a somewhat bet-

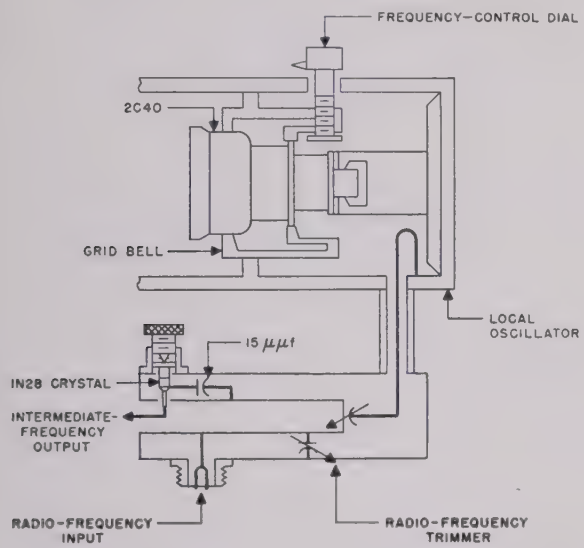

Fig. 9—Schematic diagram of the local oscillator and mixer unit for receiver.

ter over-all receiver noise-figure performance than would a tube-amplifier input circuit. However, this is only true if the if input circuit is properly designed. Fig. 10 shows a schematic of the if preamplifier, which follows the mixer.

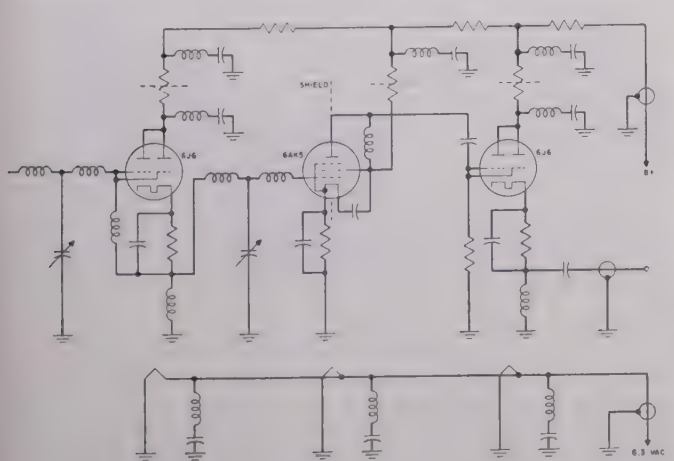

Fig. 10—Schematic circuit of the low-noise if preamplifier unit.

The preamplifier circuit has a noise figure of 2.5 db—that is, the actual circuit noise is only 2.5 db greater than the ideal limit. This is achieved by the use of triode tubes and unusual design of the input network, as well as the assembly and adjustment of the mixer and preamplifier in a single unit.

Referring to Fig. 10, the output from a high-mutual-conductance triode 6J6 used as a cathode-follower, passes to the grid of a 6AK5 through a matching network that is equivalent to a step-up transformer. The degeneration of the cathode follower allows increased input impedance, and permits the use of a triode while still providing power gain. A conventional pentode stage follows, amplifying the signal sufficiently to override the noise of following stages, and a cathode follower provides a low-impedance output circuit.

Since the total noise contributed by the tubes is considerably less than the input thermal noise, the design of the input circuit becomes a major factor. If the input impedance is adjusted to match the source, the resistance noise of the input circuit is added to the equal resistance noise of the source, doubling the noise and limiting the noise factor to not less than 3 db. For the cathode-follower circuit used, optimum noise occurs with a mismatch of about 2:1 between mixer and preamplifier.

Due to the wide bandwidth, unequal primary and secondary Q's, and large coefficient of coupling required, it was found convenient to replace the conventional input transformer by a two-section tapered filter, analogous to a tapered transmission line. This permitted the use of simple elements of inductance and capacitance, eliminating mutual inductance. Assembly of the mixer and preamplifier as a single unit eliminated the usual connecting cable; this was found highly desirable in view of the mismatch required at this point. Loading resistors are, of course, undesirable because of their thermal noise, and the loading in this case is provided almost entirely by the mixer, the amplifier input having an unloaded Q of nearly 50.

Since a cathode follower may oscillate where the sign of the cathode load (reactance) is similar to that of the grid-cathode reactance and opposite to that of the grid-ground reactance, it was necessary to select configurations for the input and output networks satisfying certain added requirements of reactance versus frequency. It was also found that an inductance approximately resonating the grid-cathode capacitance of the 6J6 above the center of the frequency band (32 Mc), improved performance by its effect on the loading reflected from the cathode circuit.

Fig. 11 shows the experimental local oscillator, mixer, and if preamplifier unit.

The main if unit is stagger-tuned, having a gain of about 75 db. Each stage is fixed-tuned, the coil wound on the basis of an average tube capacitance. No trouble was found in alignment, and change in tubes had negligible effect on band-pass characteristics. The if pre-amplifier operates directly into a 50-ohm resistor so that there is no mistuning of any input circuit. There is a manual gain control in the first stage

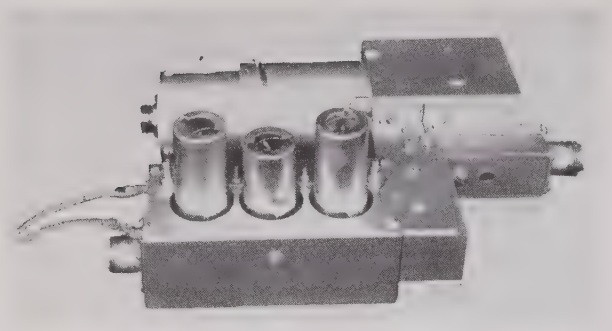

Fig. 11—Experimental local-oscillator, mixer, and if preamplifier unit.

but this, once adjusted, is left untouched. The output of the last stage operates into a plate detector for added gain and one stage of video-frequency limiting follows this. A dual cathode follower then supplies a train of pulses to the video-frequency demodulator, which has 70 ohms impedance.

Although most of the main if unit is conventional, a great deal of care must be exercised in the design and operation of the limiters for best signal-to-noise ratio. Some form of automatic volume control must be used to insure that the if stages themsleves do not limit improperly. Unlike FM (Fig. 12(a)), pulse-time-modulation requires "one-sided" limiting as shown in Fig. 12(b). Therefore, good avc action must take place. If this were not true and an if stage began limiting, the output signal-to-noise might become worse than the incoming signal-to-noise. This is shown in Figs. 12(c) and 12(d).

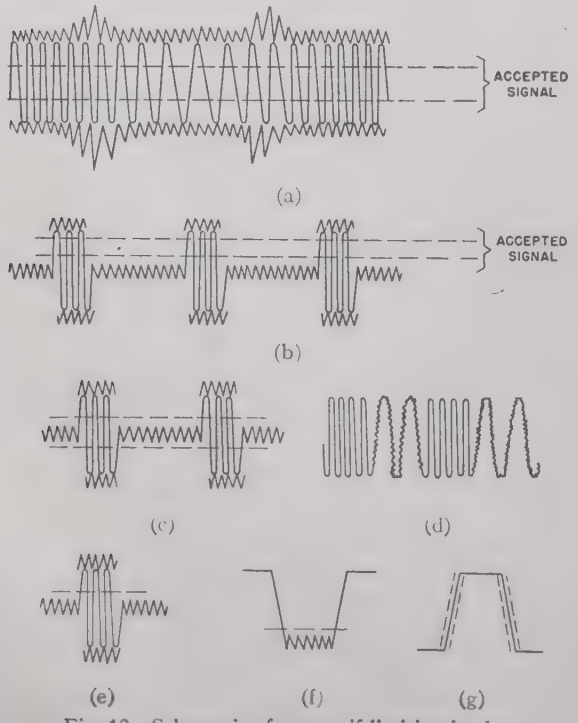

Fig. 12—Schematic of proper if limiting in the pulse-time-modulation system.

Fig. 12(c) shows what the signal may look like when applied to an amplifier that limits, and at Fig. 12(d) can be seen what appears at the output. Proper pulse-time-modulation limiting can no longer take place, as the AM signal-to-noise ratio has been degraded. In this particular if design, the type of avc was simple but effective. The last 3 stages of the strip preceding the detector contain "peak-riding" circuits in the grid with sufficiently long time constants so that no demodulation takes place. The plate detector is so biased as to remove noise on the base line. The negative output pulse is coupled to a video-frequency clipper, with dc restoring of the base line, so that top clipping of the pulse results (Figs. 12(e), 12(f), and 12(g)). Now the signal-to-noise improvement ratio of $K(\Delta Ts/t\gamma)$ can properly take place.[4] ΔTs is the pulse deviation from midposition in microseconds, $t\gamma$ is the time of pulse rise in microseconds, and K is a constant that includes the noise crest factor and ratio of pulse repetition rate to af band used. The only noise remaining is that which has been translated into time modulation. These limited time-modulated pulses are then passed to the video-frequency demodulator or to the satellite receivers.

Two types of pulse demodulators are employed, one using conventional components and another type using a special single-channel Cyclophon.[5] Both sets use the double marker for obtaining a synchronizing pulse to identify the desired channel. The marker is separated by the same process as that used in the modulator, namely, by applying the train of pulses to an open-circuited delay line. Because only the marker pulses are 1.3 microseconds apart, the first pulse after traversing the delay line is superimposed on the second pulse, producing a combined pulse larger than all others.[1] This marker pulse is selected by amplitude from the train of channel pulses and performs two functions, channel separation and channel demodulation.

In the first type of receiver, a delay line with taps in the same time relation as that used at the transmitter, is employed to isolate each desired channel. The separated marker pulse, as shown in Fig. 13, is widened, shaped, and transmitted along the delay line. This marker pulse is then applied to the control grid of a pentode biased to cutoff, while at the same time the entire series of pulses is applied to a second control grid. The 6AS6 is ideal for this purpose. The tube is keyed on at the appropriate time by the deblocking marker pulse, and the channel pulse is converted to amplitude modulation by "riding" the sloped top of the shaped marker pulse. Following this tube, a filter removes the pulse-frequency components and only af passes on to the speech amplifier. This method of demodulation proved simple and reliable, requiring no adjustments after the receiver was aligned

[4] B. Trevor, D. E. Dow, and W. D. Houghton, "Pulse time division radio relay," *RCA Rev.*, vol. 7, pp. 561–575; December, 1946.

[5] D. D. Grieg, J. J. Glauber, and S. Moskowitz, "The Cyclophon: a multipurpose commutator tube," Proc. I.R.E., vol. 35, pp. 1251–1257; November, 1947.

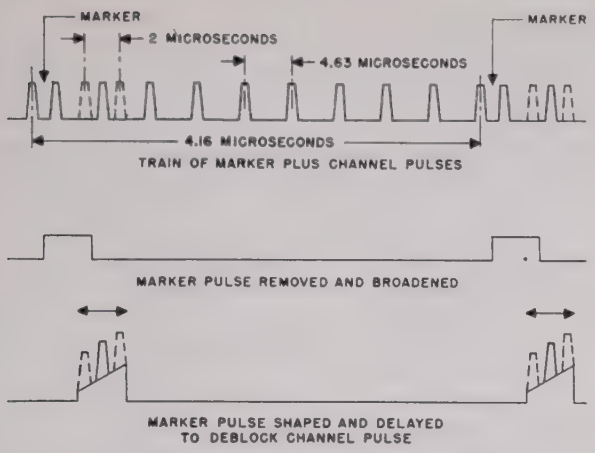

Fig. 13—Operation of marker as channel separator and demodulator.

with the transmitter. The harmonic distortion at 400 cps for the over-all system using this receiver was 2.5 per cent. The signal-to-noise ratio at 100-per cent modulation was 55 db.

A second method of channel separation and demodulation is unique in that it employs a single-channel Cyclophon. This tube, shown in Fig. 14, is comparable in size to the metal 6L6. Use of this tube eliminates a great many circuit components, including the delay line, and saves much time in receiver alignment. Although the effectiveness of the tube depends largely on stable operating voltages, little trouble has been experienced. The method of operation is straightforward. A sawtooth wave, generated by the marker pulse in a single triode, is applied to the two deflecting plates of this cathode-

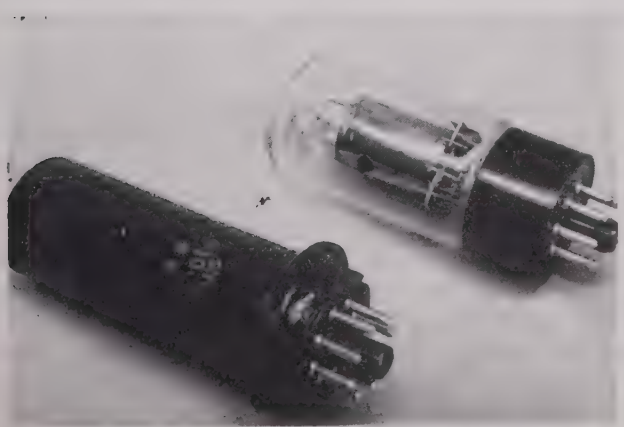

Fig. 14—Single-channel Cyclophon compared with a 6L6 metal receiving tube.

ray-type tube and sweeps the beam across a plate at the end of the tube. At the same time, all the channel pulses are applied to the control grid of the Cyclophon, and the beam is on only while a pulse is present. The beam is so focused and positioned for the selected channel that the spot striking the end plate is half on and half off for zero modulation position. For all other channels, the beam is entirely away from the plate and produces no output. The plate current, flowing through the output load resistance, is proportional to the position of the beam as determined by the timing of the pulse.[5] Hence, the output amplitude is proportional to the time modulation of the keying pulse. Channel selection takes place by merely shifting the centering voltage on the deflecting plates of this tube. Fig. 15 illustrates this process.

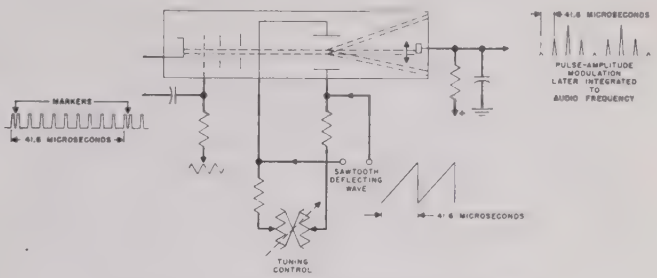

Fig. 15—Cyclophon demodulation process.

VII. Conclusions

The equipment described above was developed and operated for over a year, during which frequent tests and demonstrations were made to show its performance and versatility. From this experience the following conclusions are possible:

A. Multiplex broadcasting appears feasible anywhere within the ultra-high-frequency spectrum.

B. Over-all performance equivalent to or better than that required in standard broadcasting can be obtained at many locations. More comparative propagation data at ultra-high-frequencies are necessary before more precise conclusions can be drawn.

C. The inherent advantages of high-efficiency and high-gain antenna systems at ultra-high frequencies can be easily and economically realized in this system.

D. Because of the antenna gain, the transmitter size and power may be considerably reduced in comparison with equipment for lower frequencies.

E. Multiplex broadcasting receivers are little, if any, more complicated than standard AM or FM receivers of comparable quality. However, for any widespread use of multiplex broadcasting, the economics of the receiver is the major problem to be faced. The possible use of an inexpensive multiplexing attachment for a standard AM or FM receiver should be considered carefully.

VIII. Acknowledgment

As is true of most projects of this type and magnitude, many more people presented useful ideas and comments than can be listed here. Among those who contributed most substantially to the development of the various components that made up the complete system were R. T. Adams, D. D. Grieg, A. Horvath, A. Lesti, S. Moskowitz, and B. Parzen, all of Federal Telecommunication Laboratories.

Pulse Modulation*

E. M. DELORAINE†, FELLOW, IRE

Summary—The broad significance of pulse modulation is dealt with from its original concept through the various methods of attaining it. Its application to time-division multichannel systems is considered. More recent developments in pulse-count-modulation systems, and also potential applications to switching problems, are described.

1. The Origin of Pulse Modulation

THE CLASSICAL CONCEPT of transmission of speech by electrical means involves converting the sound vibrations into currents, one characteristic of which, amplitude or phase, is made to vary according to the sound intensity as a continuous curve versus time and an inverse operation at the receiving end. In the last few years, however, other methods have been used, in which the transmission of any speech channel occupies but a fraction of the time, the information being transmitted by samples or current pulses recurring at a suitable rate. These methods are known under the general name of "pulse modulation."

The early publications on pulse modulation are found mostly in the form of patents.[1] A review of these indicates that up to 1935 the thinking of the authors was very often in terms of improving the power efficiency of the transmission system, either at the transmitter or in the link.

Since 1935, however, more and more consideration has been given to pulse modulation as a method of multiplexing a number of telephone channels.

The accepted technique in multichannelling has been to take each individual telephone frequency band and translate it to successive positions in the spectrum of frequencies by means of modulators and filters, transmit this information on a single path, and perform the inverse operation at the other end of the link. The bandwidth utilized on the link increases, of course, in direct proportion to the number of channels. A typical layout of a multichannel transmission system by frequency division is shown in Fig. 1.

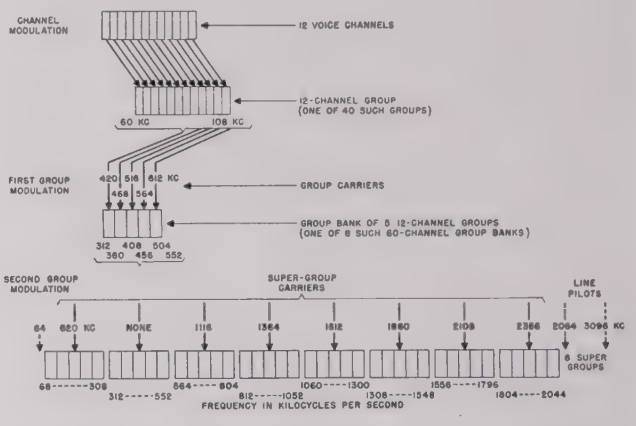

Fig. 1—Typical layout of a multiplex transmission system by frequency division.

The technical literature on these subjects at this time is very abundant. These elements have reached a high degree of perfection and practicability.

Terminal equipments were thus realized which were capable of reproducing the speech in any individual channel with high fidelity. The other parts of the transmission system had to be improved accordingly, and rather severe requirements had to be placed on them as to limitation of nonlinear distortion to avoid crosstalk between channels, stability of characteristics, and noise level.

While fully acknowledging the remarkable success of the frequency-division transmission system, Reeves and others[2] took an interest in 1936 and the following years in the possible merits of multichannel systems based on the concept of time distribution, translating into the telephone art some of the well-established practices of multichannel telegraphy. The attractive feature of the idea was that such methods might prove especially useful where it is difficult or expensive to attain the quality of characteristics required for reliable multichannel transmission on a frequency-division basis.

2. Application of Pulse Modulation to Time Multiplexing

The basis of pulse-modulation time multiplexing is the fact that it is not necessary to transmit the complex wave form of a speech wave in its entirety. It is sufficient to take successive "samples" of the amplitude in the channel at separate time intervals and transmit this in-

* Decimal classification: R148.6. Original manuscript received by the Institute, September 27, 1948. Presented, 1948 IRE National Convention, New York, N. Y., March 24, 1948.

† International Telephone and Telegraph Corp., New York, N. Y.

[1] Among such patents can be cited:

Name	*United States Patent Number*	*Filing Date*
R. A. Heising	1,655,543	April 18, 1924
R. D. Kell	2,061,734	September 29, 1934
K. Posthumus and C. G. A. VonLindern	2,161,087	December 17, 1935
A. M. Nilcolson	2,021,743	June 13, 1930
R. M. Ranger	1,873,786	September 29, 1928
A. S. Riggs	2,048,081	April 29, 1933
R. E. Shelby	2,171,150	September 14, 1936
D. G. C. Luck	2,113,214	October 29, 1936
G. Bozzi (Italian Patent)	348,656	February 8, 1937

[2] E. M. Deloraine and A. H. Reeves, United States Patent number 2,262,838, filed, November 8, 1938.

formation as a series of pulses carrying the information, as indicated in Fig. 2. If the number of samples per

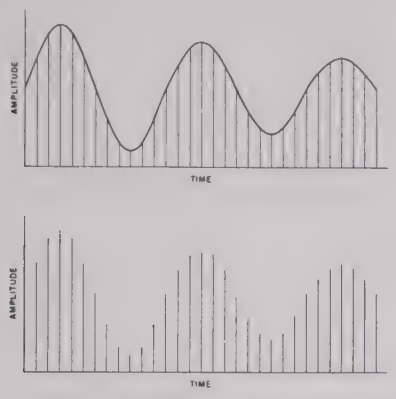

Fig. 2—Sampling of speech.

second exceeds twice the highest frequency to be transmitted in the voice band, the telephone channel can be correctly reproduced at the distant end.

The bandwidth required in the transmission medium through which the pulses are propagated depends on the shape of these sampling pulses, and the method adopted for carrying the information on pulses.

A number of incoming telephone channels can be sampled at time intervals that are displaced in the time scale just enough to avoid the superposition in time of any two pulses. The successive samples of telephone channel number 1 will be followed by the successive samples of telephone channel number 2 and so on until the whole time interval between two samples of channel number 1 is completely filled, as shown in Fig. 3.

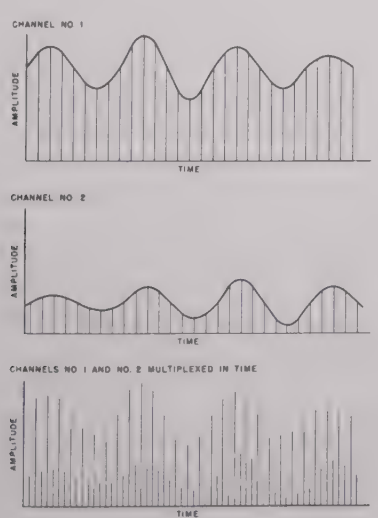

Fig. 3—Pulse-time multiplexing.

It is clear, in consequence, that the number of channels that can be transmitted over a single link increases as the individual samples are made shorter. If the time is used in the most efficient manner, the bandwidth required for the transmission of n channels is close to n times the bandwidth of an individual channel, as is the case for multichannel systems utilizing frequency division.

3. Methods of Pulse Modulation

Pulse-Amplitude Modulation

The samples of speech amplitude can be transmitted as such. This is pulse-amplitude modulation. This method is efficient in utilization of bandwidth. The requirements on the link for nonlinear distortion are, however, less stringent than for the frequency-division method, since, at a given time, one channel only is present and crosstalk cannot be introduced in this manner, though it can reappear in a different manner if the pulses are lengthened by the transmission link so as to overlap each other to a certain extent. The requirements as to link stability and low noise are not changed materially.

It is the consideration of signal-to-noise-ratio improvement, particularly for radio links, that drew attention to other possible methods of pulse modulation.

Pulse-Width Modulation

One of the first methods to be considered was pulse-width modulation, which inherently requires more bandwidth than pulse amplitude modulation, but provides a means to trade that increase in bandwidth for an improvement in the signal-to-noise ratio. Pulse-width modulation is not, however, economical or efficient in power insofar as the significant information is, in fact, the timing of the beginning and the end of individual pulses, and this led to the next method.

Pulse-Time Modulation

It was suggested that pulses of constant amplitude, form, and duration should be used, these pulses being displaced in time from a uniform spacing to an extent corresponding to the amplitude of the sample. This is more efficient than transmitting the beginning and end of pulses modulated in width, since the amplitude is translated in time displacement of one pulse, from a reference position which, however, is not transmitted except as a marker for all channels. This is usually referred to as pulse-position or pulse-time modulation.[3] As compared to pulse-amplitude modulation, the number of channels that can be transmitted over a given bandwidth is reduced. If we assume, for instance, that the individual pulse is time-modulated only to the extent of its own duration, the number of channels is divided by two. But a major advantage is that the link need not have linear amplitude characteristics. The repeaters operate as triggers, with the requirement, however, that they must trigger accurately in time. The possible variations of level in the link are compensated

[3] A. H. Reeves, French Patent 833,929, filed, June 18, 1937; and addition 49,159, filed, July 5, 1937; and United States Patent number 2,266,401, filed, June 9, 1938.

by the trigger action, since the output level of the repeaters is independent of the input level between wide limits. This method provides a means to trade bandwidth for a signal-to-noise ratio comparable with that obtained with frequency modulation. Noise is introduced in the system to the extent only that it will change the timing of the pulse, so that the influence of a given noise amplitude in the link decreases as the pulses become sharper and also as the time displacement due to modulation is increased. This method of improving the signal-to-noise ratio has been found desirable in applications to radio links, though it is paid for by a reduction in the number of channels for a given transmission bandwidth.

4. Pulsed Frequency Modulation

Another pulse-modulation method for radio links in which the pulses remain constant in time position, as well as in amplitude and duration can be designated as pulsed frequency modulation.

The information is transmitted by means of a change in the carrier frequency of each individual pulse, which is made to vary proportionally to the amplitude sample at the corresponding time. The frequency modulation brings in a signal-to-noise improvement, which involves additional requirements in bandwidth. The utilization of the total bandwidth improves, however, as the number of channels is increased, because the additional band required for frequency modulation and a given signal-to-noise improvement becomes a smaller fraction of the bandwidth required for the correct transmission of the pulse shape.

5. Pulse-Count (or Code) Modulation

The assimilation of telephone transmission to telegraph transmission becomes still closer in a method suggested by Reeves.[4] Not only is the speech curve sampled, but the amplitude samples are submitted to two successive transformations: quantization, and counting or coding.

By quantization is meant the process by which the amplitude sample is not sent with its exact value but is approximated to one of a finite number of discrete levels, as shown in Fig. 4. It is clear that, when such a series of quantized pulses is sent into a low-pass filter cutting off at the maximum speech frequency which it is thought proper to reproduce, the result will show some distortion due to the effect of the difference between the quantized and exact amplitude samples. This distortion obviously will decrease when the number of quanta is increased for any given maximum amplitude.

At the receiving end, a method which discriminates against amplitudes that do not correspond to a quanta is used. This is capable of eliminating forms of speech

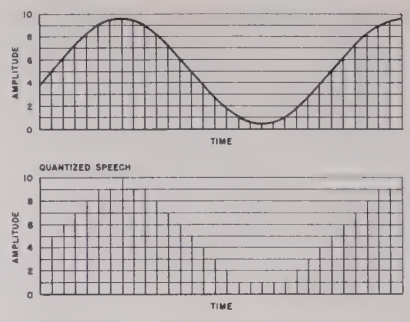

Fig. 4—Quantization of sampled speech amplitudes.

impairment introduced in the transmission systems, if they can be distinguished from the quanta.

While the advantages of speech quantization do not necessarily apply only to pulse modulation, it is of interest to combine the two processes. However, a third step can be taken with advantage.

Instead of transmitting the series of quantized amplitudes directly over the line or through space, a third transformation is performed, which is counting or coding. The information, that it is really necessary to communicate is the number of quanta present in any particular amplitude sample; this can be achieved by the transmission of a group of pulses, n for instance, each one having s possible characteristics. The total number of distinguishable levels will be $q = s^n$, and such a mechanism will thus allow the counting of q different levels. Thus, a group of five pulses of the on-or-off type can be used to count $2^5 = 32$ quantized levels in a manner similar to what is done in teleprinter signal transmission. In this instance, where $s = 2$, the system is a binary one. Other values for s can obviously be utilized, and ternary systems, for instance, have been considered particularly for wire transmission.

The fundamental advantage of binary or ternary systems is that the demodulation process consists in merely acknowledging the presence or absence of a pulse of a definite type at a definite time position. In the case of the binary code, the number of errors will fall to an insignificant value provided the pulse amplitude remains sufficiently larger than the noise rms amplitude. For instance, for a binary code and pure random noise a ratio of 18 db in rms signal-to-noise ratio will be sufficient to provide a signal-to-noise ratio in the order of 70 db after demodulation.

Because of the fact that noise in the demodulated signal originates in the random distribution of noise bursts above its rms value, the signal-to-noise improvement follows a very different law from that which it does in pulse-time modulation or frequency modulation.

In all cases, the relation between demodulated and input signal-to-noise ratios can be determined theoretically with a sufficient simplicity in the case when the signal amplitude is noticeably larger than the noise rms value. Above that threshold, the two ratios vary in direct proportion for pulse-time modulation and fre-

[4] A. H. Reeves, French Patent number 852,183, filed, October 3, 1938; and United States Patent number 2,272,070, filed, November 22, 1939.

quency modulation. For pulse-count modulation, however, the proportionality holds between input signal-to-noise in power ratio and demodulated signal-to-noise ratio in db.[5] Thus, lowering the input power ratio by 3 db brings the output ratio down to 35 db, and increasing it by 3 db brings the output ratio up to 140 db.

The effect of noise in the latter case thus becomes entirely negligible. This advantage is paid for by the distortion that quantization brings in and the additional bandwidth that the counting process necessitates. If f is the maximum frequency that it is proposed to transmit by voice channel, and n is the number of pulses per group, then the bandwidth per channel should be somewhat larger than n times f.

6. Time Versus Frequency Translation Multiplexing

The technique of modern telecommunication equipments shows a definite trend toward systems that permit of multiplexing a great number of telephone channels. These channels in turn can be used for telegraph or facsimile communication. Time multiplexing by means of pulse modulation is a solution that presents some interesting features.

One common advantage belonging to all pulse methods is the comparative ease with which any particular channel can be dropped and reinserted at any repeating point. This necessitates a complicated and formidable array of modulating and filtering apparatus when frequency division is utilized. However, in pulse transmission this may be accomplished simply by gating out every n^{th} pulse or group of pulses following the marker signal. Each channel keeps its individuality throughout the link, whereas in frequency-division technique, the economic considerations lead to a definite grouping of the channels.

Pulse transmission eases up the requirement for linearity in repeater equipments. This advantage is less marked on cables where very linear amplifiers are available and where propagation characteristics can be kept nearly constant and large signal-to-noise ratios maintained even for transmission through a great number of repeaters. It is definitely favorable for radio transmission where such conditions are not encountered. In this respect, pulse-count modulation would seem to be specially advantageous, since regenerative relays can be used in this case, reshaping the pulses at any repeating point. A very small signal increase is sufficient to provide for the required signal-to-noise ratio at the end of the chain.

The more general aspect of the integration of radio-relay links into networks needs also to be considered. Should microwave radio demonstrate its ability to carry a large volume of intercity communications economically, then those transmission methods that are best adapted to radio might be extended to certain other parts of the network if justified.

7. Switching

One interesting feature of pulse transmission in this respect is the possibility of switching channels. A number n of incoming telephone channels, after going through a simultaneous time-sampling operation, can be multiplexed in any desired time sequence by the insertion of suitable delays in the individual channels. Time scanning of the group could connect the individual incoming channels on outgoing terminals in an order determined by the value of the individual channel delay. By changing the value of the time delay introduced in the individual channels, the channel could be effectively switched between incoming and outgoing terminals in any desired manner. A typical example of switching by time displacement is shown in Fig. 5.

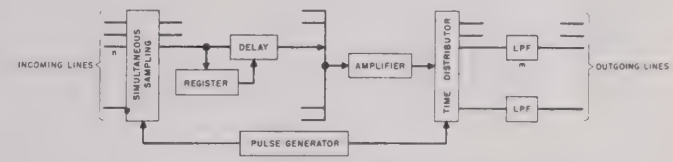

Fig. 5—A typical example of switching by time displacement.

If a multiplex pulse-transmission system is utilized, the switching operation also can be performed, but the individual pulse channels must first be isolated by a gating operation and passed through individual delay lines, and then reinserted in the multiplex system. At the receiving end, these channels would appear in an order that is determined by the value of the delays inserted.

The delays, which determine interconnection of channels between the ends of the system, may be actual time delays or the equivalent. It is possible to conceive that the delay may be introduced by counting units of time after the arrival of the incoming channel pulses. Such a counting operation can be performed by gas tubes designed for the purpose, the units of time being supplied by a common control element.

Many other methods to attain the same results in this comparatively new field of switching pulse-modulated channels can be visualized, but it is very difficult, at the present time, to evaluate their relative merits.

Pulse, being of the nature of telegraph technique, obviously offers possibilities in the telegraph field; and as switching, as described above, is effected by means which are essentially of a telegraph nature, it can play its part too.

If the use of the imagination is allowed, rather than established technical and economic facts, it is possible to visualize methods of transmission and switching using pulse modulation, which may permit a useful combination of these two fields which have so far been separate, with an ultimate gain in the complete network.

[5] A. G. Clavier, P. F. Panter, and W. Dite, "Signal-to-noise-ratio improvement in a PCM system," Proc. I.R.E., vol. 37, pp. 355–359; April, 1949.

Contributors to Waves and Electrons Section

J. T. Acker was born in Brooklyn, N. Y., in November, 1902. He is a graduate of the College of the City of New York, and also holds the S.M. degree in chemical engineering practice from the Massachusetts Institute of Technology. He was associated with the Bell Telephone Laboratories, Inc., in New York, N. Y., for eighteen years, engaged in research and development work on electrochemical and corrosion problems. In 1943 Mr. Acker transferred to the Western Electric Company to supervise the chemical operations in electron-tube manufacture. He is now assistant superintendent of manufacturing engineering in the Electronics Shops, located in Allentown, Pa.

J. T. Acker

Mr. Acker is a member of the American Chemical Society.

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John W. Coltman was born in Cleveland, Ohio, in 1916. He was graduated from the Case Institute of Technology in 1937 with the B.S. degree in physics, and was later awarded the degrees of M.S. and Ph.D. from the University of Illinois. In 1941 he was given a Research Fellowship at the Westinghouse Research Laboratories. When wartime needs gave radar development top priority, Dr. Coltman turned to microwave research, specializing in magnetron development. In 1948 he won recognition in connection with the development of a unique X-ray "telescope" that provides a 500-times brighter image for X-ray fluoroscopic screens.

John W. Coltman

Dr. Coltman is co-inventor with Dr. Fitz-Hugh Marshall of the scintillation counter. In 1949 he became manager of the electronics and nuclear physics department of the Westinghouse Research Laboratories.

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E. M. Deloraine (M'25–F'41) was born in Paris, France, on May 16, 1898. He received the B.S. degrees, the Certificat de Mathematiques in 1918, and the Enginieur Deplomié de L'ecole de Physique et Chimie, a branch of Paris University, in 1920.

E. M. Deloraine

In 1917 he joined the French Army Signal Corps, and later engaged in research work at the Eiffel Tower. He became associated with the London engineering staff of the International Western Electric Co., in 1921, becoming European technical director of the company in 1933. Later he directed experiments in connection with automatic radio compasses for aircraft.

Mr. Deloraine came to the United States in 1941 to take charge of the organization of the laboratories unit for the Federal Telephone and Radio Corp. In 1945 he was appointed president of International Telecommunication Laboratories, Inc., under the sponsorship of IT&T, where he became technical director in 1946, as well as vice-president of International Standard Electric Corp.

Mr. Deloraine was made a Chevalier of the Legion of Honor in 1938, and he was elected vice-president of the French Institute of Radio Engineers in 1939. He has been a member of the International Consultative Committee of Long Distance Telephony since 1927, and is also a member of the French Astronomical Society and a fellow of the American Institute of Electrical Engineers. He was Vice-President of the IRE in 1946.

❖

Armig G. Kandoian (S'35–A'36–SM'44) was born in Van, Armenia, on November 28, 1911. He received the B.S. degree in 1934 and the M.S. degree in electrical communication engineering in 1935, both from the Harvard University. Since 1935, Mr. Kandoian has been with the International Telephone and Telegraph Corporation and associated companies. His work has been primarily developments dealing with antennas, radiation, measurements, link communication, and air navigation. He is at present head of the radio and radar components division of Federal Telecommunication Laboratories.

Armig G. Kandoian

Mr. Kandoian received the honorable mention award in the Eta Kappa Nu recognition of outstanding young electrical engineers for 1943. He is a member of Tau Beta Pi, Harvard Engineering Society, and the American Institute of Electrical Engineers.

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Arnold M. Levine (A'44) was born on August 15, 1916, at Preston, Conn. In 1940 he received the M.S. degree in electrical engineering from the University of Iowa. He joined the sound department laboratories of the Columbia Broadcasting System in New York, N. Y. In 1942, he came to Federal Telecommunication Laboratories to work on radio circuits and systems, and is now the department head of the Communications Division for the Laboratories.

Arnold M. Levine

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Robert L. McCormack (A'41–SM'48) was born in Rochester, N. Y., on September 11, 1911. He received the S.B. degree in electrical engineering from the Massachusetts Institute of Technology in 1933. From 1933 to 1938 he was employed by the Hygrade-Sylvania Corporation as a radio tube engineer. Since 1938 he has been associated with the Raytheon Manufacturing Company, Newton, Mass. At present, he is in charge of the Development and Process Engineering Departments of the Special-Purpose Tube Division of that company.

R. L. McCormack

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Ben S. Melton (SM'47) was born in Dallas, Tex., on January 2, 1904. He received the B.S. degree in electrical engineering from the Rice Institute in 1925. Following a student engineering course at the General Electric Co. and a short time as engineer with the Gulf States Utilities Co. at Port Arthur and Beaumont, Tex., he was employed by the General Exploration Co. of Houston, Tex., to do research and development work in electromagnetic prospecting for oil, during the years 1928 to 1930. Late in 1930 he entered the field of seismograph prospecting with Geophysical Service, Inc., of Dallas, Tex., and except for a short period remained in that work until 1942, becoming associated with the National Geophysical Co., from 1937 until April, 1942.

Ben S. Melton

In 1942 Mr. Melton joined the staff of the Applied Physics Laboratory of The Johns Hopkins University as a radio engineer, working on the proximity-fuze project which was then at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Following assignment to several associated projects, he entered the research program on supersonic aerodynamics which was initiated toward the close of the war, being most recently engaged in development of optical and other methods for examining supersonic flow. In December, 1948, he accepted an appointment with the Department of the Air Force, and is now attached to the 1009th Special Weapons Squadron, Washington, D. C.

Mr. Melton is a member of the Society of Exploration Geophysicists, the American Geophysical Union, and the Philosophical Society of Washington.

Abstracts and References

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Acoustics and Audio Frequencies..... 707
Antennas and Transmission Lines..... 708
Circuits and Circuit Elements..... 709
General Physics..... 711
Geophysical and Extraterrestrial Phenomena..... 712
Location and Aids to Navigation..... 713
Materials and Subsidiary Techniques... 713
Mathematics..... 714
Measurements and Test Gear..... 714
Other Applications of Radio and Electronics..... 715
Propagation of Waves..... 716
Reception..... 717
Stations and Communication Systems.. 717
Subsidiary Apparatus..... 719
Television and Phototelegraphy..... 719
Transmission..... 719
Vacuum Tubes and Thermionics..... 719
Miscellaneous..... 720

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ACOUSTICS AND AUDIO FREQUENCIES

534 1251

Sound—E. G. Richardson. (*Rep. Progr. Phys.*, vol. 9, pp. 228–253; 1942–1943. Bibliography, pp. 253–255.) A general discussion, covering propagation in free media, ultrasonics, vibrating systems, acoustic impedance and properties of materials, speech and hearing, etc.

534 1252

Sound—E. G. Richardson. (*Rep. Progr. Phys.*, vol. 10, pp. 120–128; 1944–1945.) Discussion of auditorium acoustics, metallurgical applications of ultrasonics, musical scales, and tuning. See also 1251 above.

534 1253

Some Recent Developments in Applied Acoustics—R. G. Bolt and L. L. Beranek. (*Atti del Congresso internazionale della Radio* (Rome), pp. 225–251; September and October, 1947. In English.) Adequate progress has already been made with the understanding of (a) the basic principles of many electroacoustic instruments, (b) speech and hearing, though many physiological and psychological phenomena are still unexplained, and (c) the control of sound by porous absorptive materials. Further work is needed on (a) the transient response of loudspeakers and complicated coupled systems, (b) the study of all kinds of distortion, and (c) the design of studios for music.

534.001.8 1254

Generation of Sonic and Ultrasonic Waves in Liquids for Industrial Purposes—Janovsky and Pohlman. (*See* 1442.)

534.321.9:621.391.63 1255

On the Modulation of Light at Radio Frequencies by means of Ultrasonic Waves—A. Giacomini. (*Atti del Congresso internazionale della Radio* (Rome), pp. 302–311; September and October, 1947. In Italian.) See also 1847 of 1948.

534.44 1256

Electrical Methods of Sound Analysis—H. Koschel. (*Fernmeldetech. Z.*, vol. 1, pp. 237–244; December, 1948.) An outline of the following methods: (a) Fourier analysis of oscillograms, (b) use of octave band-filters with oscillograph, (c) sonic-frequency spectrometer with 27 filters in parallel, each covering $\frac{1}{3}$ octave, (d) search-tone analysis, (e) analysis by means of an acoustic diffraction grating, (f) analysis with an optical raster, and (g) visible-speech methods.

534.6 1257

The Double Crystal Acoustic Interferometer—W. J. Fry. (*Jour. Acous. Soc. Amer.*, vol. 21, pp. 17–28; January, 1949.) A one-dimensional theory of operation is discussed. This is sufficiently general to include both resonance and off-resonance operation, and any amount of acoustic loading of the crystals.

534.6:621.396.611.21 1258

Low-Loss Crystal Systems—Fry. (*See* 1326.)

534.756 1259

Hearing: Part 1—The Cochlea as a Frequency Analyzer—T. Gold and R. J. Pumphrey. (*Proc. Roy. Soc. B*, vol. 135, pp. 462–491; December 14, 1948.) Possible methods of sensory appreciation of sounds are briefly surveyed. Information must, in general, be lost unless peripheral frequency analysis occurs under certain conditions which include proportionality between the frequency and the selectivity of the resonant elements. Experimental evidence is submitted which shows that this selectivity is very much higher than has been supposed and is roughly proportional to frequency, and that only the Helmholtz resonance theory, suitably interpreted, is consistent with observation. Evidence of high cochlear damping is criticized. The ear appears to be a perfect frequency analyzer up to 1 kc; at higher frequencies, it is imperfect because of the limited number of resonant elements and nerve cells available. Part 2: 1260 below.

534.756 1260

Hearing: Part 2—The Physical Basis of the Action of the Cochlea—T. Gold. (*Proc. Roy. Soc. B*, vol. 135, pp. 492–498; December 14, 1948.) An attempt is made to explain observed results theoretically. The values of Q for a string immersed in water (to simulate the basilar membrane immersed in its liquid) are much lower than those obtained for the human ear. For this reason, the hypothesis that the cochlea behaves like a regenerative radio receiver is proposed. Part 1: 1259 above.

534.78 1261

Speech Communication under Conditions of Deafness or Loud Noise—W. G. Radley (*Jour. IEE* (London), part I, vol. 95, pp. 544–545; December, 1948.) Discussion on 2690 of 1948.

534.78 1262

Statistical Measurements of Vocal Intensity—G. Sacerdote. (*Atti del Congresso internazionale della Radio* (Rome), pp. 389–401; September and October, 1947. In Italian.)

534.782 1263

On a Model of an Artificial Voice for Electroacoustic Technique—P. Chavasse. (*Atti del Congresso internazionale della Radio* (Rome), pp. 273–279; September and October, 1947. In French.) A sound source whose intensity is nearly uniform with frequency is provided by an emf from a neon tube suitably polarized, associated with an amplifier and a loudspeaker. Any desired quality of voice can be obtained by adding a system of filters.

534.844/.845 1264

The Absorption Coefficient of Resonators—G. G. Sacerdote. (*Alta Frequenza*, vol. 17, pp. 217–219; October, 1948. In Italian, with English, French, and German summaries.) Curves show the reverberation times as a function of frequency for a room (a) without and (b) with a cellular lining consisting of tubular resonators. From these curves, the absorption coefficient of a partition formed of the resonators is derived for the frequency range 300 to 2,000 cps.

534.844.1 1265

The Practical Determination of the Reverberation Time of a Room with the Cathode-Ray Oscillograph—A. Moles. (*Radio Franç.*, pp. 4–8; February, 1949.) Reverberation curves can be photographed directly on slowly moving film (4 to 10 cm per second) without using the cro timebase, or on a stationary film, in which case, the necessary slow sweep is obtained by means of a rotary potentiometer of about 5,000Ω, which is shunted across a 150-volt source and supplies a variable voltage to the deflecting plates. The potentiometer is driven by a small motor of the type used for car windscreen wipers. Typical oscillograms thus obtained are given and the method of calculating the reverberation time, taking account of oscillogram irregularities, is explained in detail with numerical examples.

534.86 1266

Listeners' Sound-Level Preferences—T. Somerville and S. F. Brownless. (*BBC Quart.*, vol. 3, pp. 245–250; January, 1949.) A sound-level meter incorporates a weighting network which simulates the response of the ear. Members of the public of varying ages, BBC engineers and musicians were tested with this device; results obtained are shown graphically.

The preferred maximum sound level of the four types of program chosen for the tests appears to decrease as the age of the listener increases.

534.861:621.396.621 1267
The Acoustics of Broadcasting Receivers—V. A. Govyadinov. (*Radiotekhnika* (Moscow), vol. 3, pp. 88–95; November and December, 1948. In Russian.)

621.395.61 1268
A New Moving-Coil Microphone—H. J. Griese. (*Fernmeldetech. Z.*, vol. 1, pp. 227–232; December, 1948.) Details of an instrument with a sensibly flat characteristic up to 6 kc for sound incident normally on the diaphragm and up to 10 kc for lateral incidence. The directional diagram is spherical up to about 1,500 cps; for higher frequencies, it is slightly pear-sahped. Sensitivity is good and nonlinear distortion low.

621.395.61/.62:621.315.612 1269
Application of Activated Ceramics to Transducers—H. W. Koren. (*Jour. Acous. Soc. Amer.*, vol. 21, p. 62; January, 1949.) Summary of Acoustical Society of America paper. Titanate ceramics can be made to have piezoelectric properties suitable for application to transducers if (a) the Curie point is well above the working temperature, (b) the material is polarized by means of an external voltage source within certain limits of potential gradient and time duration. Multilayer strips have been developed to provide the low mechanical impedance required in phonograph pickups, microphones, etc.

621.395.625.6 1270
Volume Compressors for Sound Recording—W. K. Grimwood. (*Jour. Soc. Mot. Pic. Eng.*, vol. 52, pp. 49–76; January, 1949.) Discussion of the desirability of volume compression, compressor characteristics, classification, performance measurement, and the relative merits of various types.

621.395.667 1271
On Lower- and Upper-Register RC Equalizers for Audio Frequencies—W. Daudt. (*Funk und Ton*, vol. 3, pp. 33–42 and 86–92; January and February, 1949.) A general treatment, with design formulas and curves, and detailed discussion of three particular cases. A design is given for a resistance amplifier with correction at both ends of the af range.

621.395.667 1272
Simple Tone Control Circuit—E. J. James. (*Wireless World*, vol. 55, pp. 48–50; February, 1949.) Adequate reduction or increase of bass or treble is obtained for normal requirements. Only resistors and capacitors are required. The complete circuit diagram for including the control in an amplifier is given.

ANTENNAS AND TRANSMISSION LINES

621.3.091:621.315.2 1273
Attenuation in Air-Space Cables for Centimetre Waves—H. J. Wegener and O. Zinke. (*Frequenz*, vol. 2, pp. 203–207; August, 1948.) Diagrams show directly the reduction of attenuation, compared with that of a coaxial cable for *TM* and *TE* waves, a function of frequency and cable diameter. From other diagrams, the optimum diameter for a given value of attenuation can be found for any wavelength in the range 1 to 15 cm. For wavelengths of 2.5, 5, 7.5, and 10 cm, the dependence of attenuation on cable diameter is shown for all types of air-space cables. For wavelengths <2.5 cm the attenuation for H_{11} waves is less than for H_{10} waves.

621.315.012:518.3 1274
R. F. Transmission Line Nomographs—P. H. Smith. (*Electronics*, vol. 22, pp. 112–117; February, 1949.) 10 abacs for calculating characteristic impedance, high-frequency resistance, current-phase relationship, voltage gradient, SWR, etc.

621.315.2+621.394/.395 1275
French Telecommunication Networks—Mailley; Gastebois. (*See* 1492.)

621.315.2+621.394/.395].66 1276
Construction of Cables and Loading Coils—R. Belus. (*Câbles and Trans.* (Paris), vol. 3, pp. 31–47; January, 1949. With English summary.) Developments in technique from 1924 to 1949.

621.315.2 1277
The Laying of Long-Distance Cables—M. Troublé. (*Câbles and Trans.* (Paris), vol. 3, pp. 48–65; January, 1949. With English summary.) Historical review of French methods.

621.315.212:621.392.5 1278
Coaxial Cable with High Characteristic Impedance—J. A. Hodelin. (*Radio Franç.*, no. 2, pp. 23–24; February, 1949.) A formula is derived for the impedance of a cable with a helix of small diameter for the central conductor. Calculated and measured values of impedance for such delay lines are in good agreement. See also 2009 of 1947 (Zimmermann).

621.315.212:621.397.5 1279
The London-Birmingham Television Cable: Part 1—General System and Electrical Requirements—H. Stanesby and W. K. Weston. (*P.O. Elec. Eng. Jour.*, vol. 41, part 4, pp. 183–188; January, 1949.) The cable has two 0.975-inch and four 0.375-inch coaxial tubes. It is designed to transmit very-high-definition or color television, 405-line television and broadband telephony simultaneously. The large tubes may ultimately transmit frequencies up to 30 Mc or more with repeaters at 3-mile intervals.

621.392.2 1280
Study of Reflections in Transmission Lines at U.H.F.—M. Bouix. (*Onde Élec.*, vol. 29, pp. 35–43; January, 1949.) The reflections caused by one, and next by two obstacles in the line are considered; an obstacle of a given length is equivalent to a unique concentrated obstacle. The case of many obstacles is then examined. In practice, the frequency is only known approximately, and, even in the case of magnetron oscillations, the frequency may jump or split into two. These differences from the nominal frequency produce phase variations of the waves reflected by obstacles, thus causing variations of the amount of the stationary waves. Assuming such phase variations to be distributed at random, the probability of good matching being obtained is considered. A practical matching method is described.

621.392.2 1281
Propagation of Plane Electromagnetic Waves in a Multi-Layer Medium of Periodic Structure—M. L. Levin. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1399–1404; November, 1948. In Russian.) The effect of equidistant dielectric spacers on the propagation of electromagnetic waves in cables and waveguides is usually considered in terms of the coefficient of reflection from a single spacer. This procedure is unsatisfactory since the equidistant spacers form a periodic structure causing dispersion of the signal and attenuating certain frequency bands. Accordingly, a dispersion equation (11) is derived, and analyzed in detail for the cases where the wavelength is (a) long, and (b) short in comparison with the distance between the spacers. Methods for determining the frequency bands attenuated are also indicated.

621.392.21 1282
Simplified Procedure for Computing Behavior of Multiconductor Lossless Transmission Lines—S. Frankel. (*Elec. Commun.* (London), vol. 25, pp. 286–290; September, 1948.) Summary noted in 2443 of 1948. The wave equation for any lossless system of parallel conductors is derived in terms of the characteristic impedance or admittance coefficients obtained directly from the partial capacitances of pairs of the conductors. Illustrative examples are discussed.

621.392.26† 1283
Theory of Symmetrical Waves in a Circular Waveguide with an Open End—L. A. Weinstein. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1543–1564; December, 1948. In Russian.) A mathematical analysis of the propagation of symmetrical electric and magnetic waves in a circular waveguide toward the open end. An integral equation (7) determining the current density in the wall of the waveguide is derived and methods for its solution are proposed. Coefficients of reflection of the waves from the open end are calculated and also the coefficients of transformation of the waves into waves of different modes. Huyghens' principle for calculating the diffraction field is discussed; formulas and graphs for determining the radiation field of the waveguide are derived. Approximate formulas of adequate accuracy involving simple calculations are also given.

621.392.26† 1284
A Note on Reflection from Dielectric Structures in Wave Guide—J. Shuoys. (*Jour. Appl. Phys.*, vol. 19, p. 797; August, 1948.) A method of representing the effect of an obstacle in a waveguide by the equivalent capacitive loading on a transmission line, valid for obstacles of small cross section.

621.392.26† 1285
The Calculation of the Critical Frequency of Waveguides with Π or H Cross-Section.—L. N. Deryugin. (*Radiotekhnika* (Moscow), vol. 3, pp. 49–61; November and December, 1948. In Russian.) General formulas are derived linking the critical frequency of the H_{10} wave with the cross-sectional dimensions of the waveguide. From these formulas, graphs are obtained for use in design work. Some limiting cases are considered separately.

621.392.26† 1286
The Theory of Disk-Loaded Wave Guides—W. W. Hansen. (*Atti del Congresso internazionale della Radio* (Rome), pp. 111–132; September and October, 1947. In English.) The phase velocity in a circular waveguide can be reduced to any desired value by introducing equally spaced baffles or disks. The group velocity can also be controlled, and the structure may be regarded as a band-pass filter. The characteristics of such structures are evaluated by various methods and shown graphically.

621.392.26†:621.3.09 1287
Theory of the Propagation of an E.M. Field along a Dielectric Waveguide of Circular Cross-Section—M. Abele. (*Atti del Congresso internazionale della Radio* (Rome), pp. 3–13; September and October, 1947. In Italian.) If the waveguide is lossless, two distinct types of electromagnetic modes can be set up in which the longitudinal components E_l, H_l of the electric and magnetic field are both present, except in the case of waves of order zero. For all other orders, there is a fundamental mode which can be propagated longitudinally whatever the frequency. All other modes possess a cut-off frequency, below which only transverse propagation is possible.

If the conductivity is small compared to the product of the frequency and the permittivity of the dielectric, the attenuation tends, for increasing frequency, to a limit independent of the mode and of the diameter of the waveguide.

621.392.26†:621.3.09 1288
Rectangular Waveguides with Several Dielectrics—M. Abele and C. M. Garelli. (*Atti del Congresso internazionale della Radio* (Rome), pp. 14–29; September and October, 1947. In Italian.) The case of two dielectrics is here considered. Results can easily be extended to the general case, provided there is symmetry about a central plane. In a metallic waveguide, dielectrics can be chosen to obtain any desired field

configuration and in particular a plane wave within a given region. Transformers and filters can be constructed in this way. The radiation diagram of a waveguide open at one end can be much altered by the use of dielectrics, and directivity can be greatly increased.

621.392.26†:621.317.335.3† 1289
Universal Curves for Dielectric-Filled Wave Guides and Microwave Dielectric Measurement Methods for Liquids—Surber. (*See* 1433.)

621.392.26†:621.392.52 1290
Maximally-Flat Filters in Waveguide—Mumford. (*See* 1320.)

621.396.67 1291
Microwave Beam-Shaping Antennas—L. J. Chu. (*Atti del Congresso internazionale della Radio* (Rome), pp. 52–64; September and October, 1947. In English.) Optical ray principles are applied to line sources with cylindrical reflectors, line sources with lenses, and point sources with double-curvature reflectors to produce radiation diagrams of any desired shape. The cosecant diagram is especially considered.

621.396.67:538.56.029.8 1292
Microwave Optics Between Parallel Conducting Sheets—H. B. DeVore and H. Iams. (*RCA Rev*, vol. 9, pp. 721–732; December, 1948.) Discussion of various microwave systems which focus in one plane only. These range from simple lens-like elements to more elaborate systems involving dielectric elements. They produce a fan-shaped beam of radiation which may be converted to a pencil beam by using cylindrical reflectors or lenses to focus in the perpendicular direction. A method of scanning in this direction is described.

621.396.67:621.396.93 1293
An Investigation of Resonances and Asymmetry in the Adcock Aerial Systems—A. Z. Fradin and V. A. Khatskelevich. (*Radiotekhnika* (Moscow), vol. 3, pp. 6–28; November and December, 1948. In Russsian.) A rigorous analysis is given of the resonance phenomena taking place in the H-type Adcock system (Fig. 1), in order to determine the type and magnitude of errors introduced into the system by asymmetry in various elements. The usual practice of identifying the frequency characteristic of the system with that of its input impedance appears in general to be incorrect.

621.396.671 1294
On the Radiation Resistance of a Radiator Surrounded by a Spherical Magneto-Dielectric Envelope—A. R. Vol'pert. (*Radiotekhnika* (Moscow), vol. 3, pp. 29–48; November and December, 1948. In Russian.) It is often necessary to reduce the physical length of a linear vibrator without decreasing its radiation resistance. Methods for increasing the effective length of the vibrator have been considered by various authors. Pistol'kors examined the effect of a dielectric envelope in the form of an infinitely long cylinder. Here a spherical envelope is considered, because this shape allows a rigorous solution (34) to be obtained, based on Maxwell's equations and the corresponding boundary conditions. This solution involves only elementary functions. The effects of the permeability and permittivity of the sphere and of its radius on the radiation resistance of the vibrator are examined in detail. The physical interpretation of the results is discussed; it can be extended to other shapes of envelope.

621.396.671 1295
Mutual Impedance of Two Centre-Driven Parallel Aerials—P. Starnecki and E. Fitch. (*Wireless Eng.*, vol. 25, pp. 385–389; December, 1948.) A formula and curves are given for symmetrically placed antennas with a sinusoidal current distribution. Measurements at frequencies from 3 to 20 Mc, using vertical antennas above a horizontal earth mat 400 feet in diameter, are in fair agreement with theory.

621.396.671 1296
Ring-Aerial Systems—H. Page. (*Wireless Eng.*, vol. 25, p. 402; December, 1948.) Correction to 308 of March.

621.396.671 1297
The Radiation Patterns of Dielectric Rods—Experiment and Theory—R. B. Watson and C. W. Horton. (*Jour. Appl. Phys.*, vol. 19, pp. 661–670; July, 1948.) The radiation from rods used as terminations to rectangular waveguides is discussed theoretically. Radiation patterns are computed from the fields due to equivalent magnetic and electric currents on the surfaces of the rods. Specific calculations are made for rods of cross section about 0.9 inch×0.25 inch and 3λ to 10λ long, in the $TE_{0,1}$ mode. Theoretical and experimental patterns for polystyrene rods 3λ to 6λ long are in agreement. Discrepancies for longer rods are discussed.

621.396.679.4 1298
A Method of Feeding Turnstile Antennas—R. E. Taylor. (*Electronics*, vol. 22, pp. 164, 170; February, 1949.) To obtain correct phasing, the dipoles are fed by separate coaxial feeders whose physical lengths are equal, but whose electrical lengths differ by $\lambda/4$. This is achieved by using different dielectric materials in the feeders. The characteristics of the feeders for the antenna used in telemetering from V-2 rockets (2536 and 3242 of 1947) are discussed.

621.396.679.4:621.392.43 1299
High-Frequency Balancing Devices—Meinke. (*See* 1314.)

621.396.671 1300
Radio Research Special Report No. 16: A Method of Determining the Polar Diagrams of Long Wire and Horizontal Rhombic Aerials [Book Notice]—W. R. Piggott. H.M. Stationery Office, London, 1948. 9d. (*Govt. Publ.* (London), p. 14; December, 1948.)

CIRCUITS AND CIRCUIT ELEMENTS

621.3.015.3:621.396.622 1301
Transient Processes in detecting an E.M.F. with a Linearly Increasing Amplitude—R. D. Leites. (*Radiotekhnika* (Moscow), vol. 3, pp. 62–75; November and December, 1948. In Russian.)

621.3.018.7:621.396.813 1302
Trapezoidal Waveform with Minimal Distortion—W. Bader. (*Frequenz*, vol. 2, p. 208; August, 1948.) Comment on 2470 of 1948 (Päsler), in which "distortion" should be substituted for "noise factor" in both title and text, and whose UDC number should be as above.

621.3.018.7:621.396.813 1303
A Representation of the Distortion Formula in Closed Form—M. Päsler. (*Frequenz*, vol. 2, pp. 208–210; August, 1948.) The so-called completeness condition (Parseval's equation), which expresses the sum of the squares of the coefficients in the series development of an arbitrary function $F(z)$ in the form of a definite integral, enables the usual expression for the distortion χ to be put into a closed form. The general formula is given and applied to the case where $F(z)$ is represented by a Fourier series. When $F(z)$ has certain symmetrical properties, relatively simple formulas for χ are obtained. See also 2470 of 1948 and 1302 above.

621.314.3† 1304
Simplified Magnetic Amplifier—M. Marinescu. (*Wireless Eng.*, vol. 25, p. 402; December, 1948.) Comment on 315 of March (Bell). An alternative type of amplifier, giving balance of output current for zero signal input, proportionality between output and input, and discrimination in the response to inputs of different polarity, is briefly discussed with illustrative diagram.

621.314.3†:623.82 1305
Magnetic Amplifiers for Shipboard Applications—L. W. Buechler. (*Elec. Eng.*, vol. 68, pp. 33–37; January, 1949.) Advantages include: ruggedness and reliability; no real limitation on power handled; no warming-up time; power can be taken direct from the 50-cps mains, although speed of response increases with increasing frequency; power gains of 1,000 to 10,000 per stage are possible with response times of 0.005 to 0.1 second; power gains up to 10^8 can be obtained with response times of 1 to 5 seconds. Design principles and relevant properties of magnetic materials are discussed.

621.318.4 1306
Calculation of Q for Single-Layer Coils—F. Benz. (*Elektrotech. und Maschinenb.*, vol. 66, pp. 7–12; January, 1949.) A formula is derived which gives results in good agreement with measured values. The effects of self-capacitance and dielectric losses and the reduction of Q by magnetic screens are discussed. A simple empirical formula is also given for the inductance of single-layer coils.

621.319:679.5 1307
Electrostatic "Magnets"—(*Elec. Times*, vol. 114, p. 696; December 9, 1948.) Electrets, dielectric bodies which can retain an electric moment after an externally applied field has been removed, can be made from certain ceramic or plastic materials. The plastics require an emf of 4 to 12 kv for satisfactory electrification. Specimens tested after a year have not changed their electrical properties appreciably.

621.319.4.011.5:519.272 1308
The Theory of Extreme Values and Its Implications in the Study of the Dielectric Strength of Paper Capacitors—B. Epstein and H. Brooks. (*Jour. Appl. Phys.*, vol. 19, pp. 544–550; June, 1948.) Statistical theory of the distribution of extreme values is used to deduce the dependence of paper-capacitor breakdown on capacitor size.

621.362 1309
Thermomagnetic Generator—L. Brillouin and H. P. Iskenderian. (*Elec. Commun.* (London), vol. 25, pp. 300–311; September, 1948.) A mathematical analysis of an electric generator using a coil wound on a core of high permeability through which a magnetic field is maintained by an external magnet. The core is heated above and cooled below the Curie point, and the resulting changes in flux induce electromotive forces in the coil. Expressions are derived for the optimum power and efficiency of such a generator.

621.385.012 1310
The Correspondence between the Static Characteristics and the Dynamic Parameters of Electrical Negative-Resistance Devices—Cartianu. (*See* 1542.)

621.385.012.8 1311
Equivalent Circuit and Input Admittance of Retarding-Field Valves—A. Pinciroli and R. Ferrero. (*Alta Frequenza*, vol. 17, pp. 196–211; October, 1948. In Italian, with English, French, and German summaries.) Assuming transit-time effects and control-grid current can be neglected, an expression is derived for the equivalent input admittance of a retarding-field tube used as a negative-transconductance triode. For the case of a resistive output impedance, the equivalent input capacitance and conductance variations are plotted as functions of the ratio of output impedance to the differential resistance of the tube, with the differential resistance as a parameter. Discussion of the case of two distinct output impedances shows that when these consist of resistances of suitable value, the input admittance can be made zero and, within certain frequency limits, independent of frequency.

621.392 1312
Relation between Amplitude and Phase in Electrical Networks—T. Murakami and M. S. Corrington. (*RCA Rev.*, vol. 9, pp. 602–631; December, 1948.) A simple graphical method is

presented for computing the phase curve from a given amplitude characteristic, and the attenuation characteristic from a given phase curve in a minimum phase-shift network. A large number of universal curves are given, to simplify the application of the theory.

621.392:517.43 1313
History of the Operational Calculus as Used in Electric Circuit Analysis—T. J. Higgins. (*Elec. Eng.*, vol. 68, pp. 42–44; January, 1949.) Bibliography, pp. 44–45.)

621.392.43:621.396.679.4 1314
High-Frequency Balancing Devices—H. H. Meinke. (*Fernmeldetech. Z.*, vol. 1, pp. 193–199; November, 1948.) Description of various arrangements for converting from an unsymmetrical feeder, such as a coaxial cable, to the symmetrical type of feeder required for a dipole.

621.392.5 1315
Equivalent Circuits of Linear Active Four-Terminal Networks—L. C. Peterson. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 593–622; October, 1948.) The representation of a triode as a linear quadripole and the concept of "effective transconductance" are examined. Electron transit-time effects and circuit behavior were considered independently in earlier theories. The present paper develops a more general theory of active linear quadripoles, in which circuit and electron stream parameters are combined in a single equivalent-circuit representation. It is shown that the equations for current or voltage equilibrium may yield a number of alternative tee or pie networks, the passive elements of which represent faithfully any three of the four independent parameters. The method is applied to grounded-cathode, grounded-grid or grounded-anode triodes, and the complete sets of quadripole parameters are listed, together with approximate parameters and equivalent circuits for moderately low frequencies.

621.392.5 1316
Generalized Quadripoles—R. Malvano. (*Atti del Congresso internazionale della Radio* (Rome), pp. 141–159; September and October, 1947. In Italian.) A general theory is developed for the case of axial symmetry, and applied to the study of filters and impedance transformers.

621.392.52 1317
New Methods of Filter Design by means of Frequency Transformations—G. Neovius. (*Kungl. Tekn. Högsk. Handl.*, Stockholm, no. 3, 40 pp.; 1946. In English.) Frequency transformations, discussed by Laurent (1339 of 1938), replace the angular frequency by a function thereof, which has the dimensions of radians per second, and also multiply all impedances by a dimensionless function. Such transformations are further examined, and a tabular method of calculation is considered and applied to the following process of filter design: (a) the required attenuation curve of the filter in the real-frequency region is converted to the negative imaginary-frequency region and plotted on a logarithmic scale; (b) an approximation to the curve thus obtained is derived from the attenuation curves of all-pass filter sections; (c) attenuation peaks are retransformed to the real-frequency region; (d) the characteristic frequencies thus obtained are used for designing L-sections which can be connected in cascade to form the requisite filter. Numerical examples are given.

621.392.52:517.53 1318
Splitting of an Analytical Function into a Linear and a Nonlinear Part, and also a Method of Determining, for a Known Linear Component, the Nonlinear Component and the Function as a Whole—Pleijel. (*See* 1422.)

621.392.52:517.727 1319
Application of sn Elliptic Functions to the Calculation of Filters—K. Steffenhagen. (*Funk und Ton*, vol. 3, pp. 44–47; January, 1949.)

621.392.52:621.392.26† 1320
Maximally-Flat Filters in Waveguide—W. W. Mumford. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 684–713; October, 1948.) Good match within the pass band and efficient suppression outside it are achieved by giving the loss characteristic the greatest possible number of zero derivatives at midband. The required loaded Qs of the resonant elements are given, and it is shown that sections of waveguide between elements reduce mutual coupling and allow the use of shunt reactances only. Loaded Qs are given for resonant cavities formed by various reactive obstacles. Up to 75 obstacles have been used in practice, giving good agreement with theory.

621.392.6:512.831 1321
Transmission Losses in $2n$-Terminal Networks—V. Belevitch. (*Jour. Appl. Phys.*, vol. 19, pp. 636–638; July, 1948.) The efficiency matrix is defined for such networks, and its application to the solution of reactive and resistive, transformer-type, and general $2n$-terminal network problems is discussed.

621.394/.395].66+621.315.2 1322
Construction of Cables and Loading Coils—Belus. (*See* 1276.)

621.396.611.1:518.4 1323
Graphical Solution of Oscillation Problems in Circuits with Negative Resistance—A. Sabbatini. (*Atti del Congresso internazionale della Radio* (Rome), pp. 374–388; September and October, 1947. In Italian.) Discussion of various circuits of the dynatron and arc types. Current versus voltage curves are obtained by a geometrical construction; a method of deducing the wave form is given.

621.396.611.1:621.3.015.3 1324
The Occurrence of Needle Impulses and their Effect on the Transient Behaviour of Forced Oscillations—M. Päsler. (*Frequenz*, vol. 2, pp. 322–331; December, 1948.)

621.396.611.1:621.317.6 1325
Erratum: Response of Linear Resonant Systems to Excitation of a Frequency Varying Linearly with Time—G. Hok. (*Jour. Appl. Phys.*, vol. 19, p. 623; July, 1948.) Correction to 671 of April.

621.396.611.21:534.6 1326
Low-Loss Crystal Systems—W. J. Fry. (*Jour. Acous. Soc. Amer.*, vol. 21, pp. 29–34; January, 1949.) Discussion of the effect of damping or resistive mechanical loads on the characteristics of a piezoelectric crystal system vibrating in either a longitudinal or a thickness mode. Results are applied to the double crystal acoustic interferometer (1257† above).

621.396.611.3:517.942 1327
On Linear Differential Equations with Slowly Variable Coefficients. Application to the Study of Nonlinear Coupling—Blanc. (*See* 1423.)

621.396.611.3:621.396.813 1328
On the Reduction of Phase Distortion in Stages with Coupled Circuits—J. Laplume. (*Compt. Rend. Acad. Sci.* (Paris), vol. 227, pp. 1213–1215; December 8, 1948.) The case of two coupled resonant circuits tuned to the same frequency is analyzed in a manner analogous to that used for stagger-tuned circuits (681 of April). It is not found possible to annul the second-degree term in the formula obtained for the phase distortion, but the third-degree term can be annulled by suitable choice of the coupling coefficient k. When both circuits have the same Q, $k=1/Q\sqrt{3}$. The top of the output amplitude curve is rounded, in agreement with a general rule given previously (40 of February).

621.396.611.4 1329
The Radiation of Oscillations from a Cavity Resonator through an Aperture as an Analogue of the Tunnel Effect—P. E. Krasnushkin and E. R. Mustel'. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1378–1393; November, 1948. In Russian.)

621.396.611.4 1330
On Avoiding Low Frequencies in a Rectangular Cavity Resonator used as Part of a Triode Generator—K. F. Niessen. (*Atti del Congresso internazionale della Radio* (Rome), pp. 312–329; September and October, 1947. In English.) A mathematical analysis of optimum shapes and proportions for resonators built up from rectangular units to exclude resonances at frequencies below that desired. Other shapes where the cross section is made up of triangles are also discussed.

621.396.611.4.029.64 1331
Design of a Resonant Cavity for Frequency Reference in the 3 cm Range—R. R. Reed. (*Atti del Congresso internazionale della Radio* (Rome), pp. 364–373; September and October, 1947. In English.) Discussion of the design and performance of a temperature-compensated resonator, suitable for quantity production, having a frequency error of less than 1 Mc and a loaded Q of 2,000.

621.396.615+621.396.645 1332
Limits of Tube-Gain and Power Output at Extreme-High Frequencies—M. J. O. Strutt. (*Atti del Congresso internazionale della Radio* (Rome), pp. 655–667; September and October, 1947. In English.) Amplifier and oscillator stages without feedback are discussed. A formula for the optimum gain is derived. The importance of the "border" frequency at which this gain drops to unity is stressed; the gain formula is transformed in various ways according to the type of reception tube to which it is applied. Grounded-cathode and grounded-grid stages are compared. The theory does not cover traveling-wave tubes, with which an effective bandwidth of 800 Mc at 3,300 Mc has been successfully amplified. Similitude rules for determining the frequency dependence of the power output of power tubes at uhf are tabulated and discussed.

621.396.615 1333
High-Stability Pilot Generator for the 3.5-Mc/s and 7-Mc/s Bands—L. Liot. (*Radio Franç.*, pp. 21–23; January, 1949.) An electron-coupled oscillator using a single EL39 tube. The tuned-plate output circuit is isolated from the oscillator by connecting the suppressor grid directly to earth. Both high- and low-impedance outputs are provided. Performance figures for different load resistances are tabulated.

621.396.615:621.396.645 1334
The Theory of the Oscillator using a Cathode-Coupled Amplifier—G. A. Khavkin. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1416–1420; November, 1948. In Russian.)

621.396.615.17 1335
Aperiodic Frequency Doubler for a Sinusoidal Electric Quantity—M. Nuovo. (*Atti del Congresso internazionale della Radio* (Rome), pp. 330–335; September and October, 1947. In Italian.) Discussion of a doubler which uses a single tube with two control grids. The doubler can operate at all frequencies for which this tube can amplify. The output is practically free from unwanted harmonics.

621.396.615.18 1336
Quasi-Aperiodic Divider for Low Acoustic Frequencies—E. Gatti. (*Atti del Congresso internazionale della Radio* (Rome), pp. 297–301; September and October, 1947. In Italian.) A very stable divider has been used for over a year to reduce a standard frequency of 100 kc to 1,000 cps. Associated apparatus to extend the reduction to 50 cps is discussed. See also 3687 of 1939 (Miller) and 1598 of 1948.

621.396.615.18 1337
Synchronous Frequency Division—P. G. Bordoni. (*Atti del Congresso internazionale*

della Radio (Rome), pp. 252–272; September and October, 1947. In Italian.) By studying mechanical oscillatory systems whose parameters vary periodically, analogous electrical circuits can be realized for frequency halving in which instability is impossible. Practical experience with two different circuits confirms theoretical predictions and shows that considerable voltage amplification and good wave form can be obtained together. Only one triode is needed for each stage of division.

621.396.645 1338

Note on the Sensitivity of an Amplifier Stage—W. Kleen. (*Ann. Radioélec.*, vol. 3, pp. 299–301; October, 1948.) Calculation shows that the signal-to-noise ratio of a grounded-grid circuit is given by the same expression as for a grounded-cathode circuit. For a given tube, therefore, the optimum sensitivities of two such amplifier stages should be the same.

621.396.645 1339

The Quasistationary Wave Amplifier—W. Kleen. (*Elektrotechnik* (Berlin), vol. 2, pp. 341–342; December, 1948.) A short discussion of distributed amplification, based on the account given by Ginzton et al. (3375 of 1948.)

621.396.645 1340

Study of Amplifiers for Square-Wave Signals—H. Gilloux. (*Radio Franç.*, pp. 6–12; January, 1949.) Methods of producing square-wave signals are briefly considered and the response of an amplifier stage to such signals is discussed with particular reference to circuit time constants. Practical design details are given for *RC*-coupled and cathode-coupled circuits. Low-frequency and high-frequency compensation methods are outlined and transformer coupling and the use of feedback are discussed. These design principles have been used for amplifiers with outputs of the order of 20 and 50 watts respectively, both having only 0.5 per cent distortion at full power and passing square-wave signals of frequencies from 25 to 15,000 cps.

621.396.645.029.3 1341

A Miniature Audio-Frequency Amplifier—W. T. Duerdoth and J. Garlick. (*P. O. Elec. Eng. Jour.*, vol. 41, part 4, pp. 228–233; January, 1949.) Discussion of the design techniques required for a line amplifier occupying a space of $2\frac{1}{2}\times2\frac{1}{2}\times4\frac{1}{2}$ inches. More than one feedback path is used.

621.396.645.37 1342

Group Transmission Time in Feedback Amplifiers—G. Schaffstein. (*Frequenz*, vol. 2, pp. 291–295; November, 1948.) The variations of phase and group transmission time due to feedback are calculated. With pure positive or negative feedback, the phase difference between input and output voltages is constant. The phase variation is greatest when the feedback voltage is 90° out of phase with respect to the input voltage. Variations of the group transmission time occur for both positive and negative feedback and for 90° phase displacement between feedback and input voltages. For pure phase feedback, the transmission-time variation is proportional to k, the ratio of feedback and input voltages, but for 90° phase displacement between feedback and input voltages the variation is proportional to k^2. For a single-stage amplifier, the gain and group transmission time vary in the same way. For a multi-stage amplifier, the transmission-time variations for the same gain variation differ according to whether (a) each of the n stages has its own feedback, or (b) feedback is applied between input and output. In the latter case, the variations are n times larger. Experiments with a 2-stage amplifier confirmed the theory.

621.396.645.371 1343

Linear Power Amplifiers in American Broadcasting—W. H. Doherty. (*Atti del Congresso internazionale della Radio* (Rome), pp. 280–291; September and October, 1947. In English.) Discussion of: (a) operating principles and practical adjustment of the Doherty amplifier, (b) the application of negative feedback to increase linearity, and (c) the advantages of this system, particularly for high-power broadcasting transmitters. See also 378 of 1940 (Doherty and Towner).

621.397.645 1344

Stagger-Peaked Video Amplifiers—A. Easton. (*Electronics*, vol. 22, pp. 118–120; February, 1949.) The use of stagger tuning to obtain a desired amplitude versus frequency characteristic was discussed in 2491 of 1948 (Wallman). A similar general principle is here applied to video amplifiers.

621.3.012:621.38.001.8 1345

Handbook of Industrial Electronic Circuits [Book Review]—J. Markus and V. Zeluff. McGraw-Hill, London, 272 pp., 39s. (*Wireless Eng.*, vol. 25, p. 400; December, 1948.) The book contains circuit diagrams, usually with typical component values and short explanatory notes. The subjects covered include af capacitance control, cathode-ray control, counters, dc amplifiers, electronic switches, limiters, measurement, metal location, motor control, multivibrators, oscillators, photoelectric circuits, power supplies, stroboscopy, telemetry, temperature control, timing, ultrasonics, voltage regulation, and welding. Only American work is mentioned.

GENERAL PHYSICS

53.081+621.3.081 1346

The Rationalized Giorgi System in the Theory of Electricity—P. Cornelius. (*Tijdschr. ned. Radiogenoot.*, vol. 14, pp. 1–9; January, 1949. In Dutch, with English summary.) Reasons are advanced for the adoption of the Giorgi system with the absolute volt and ampere. It enables the relations between electrical quantities and mechanical forces to be expressed in a particularly simple form. Maxwell's laws are presented in rationalized units.

535.215.3 1347

The Capacitor Method for Investigations of Photo-E.M.F.—S. M. Ryvkin. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1521–1542; December, 1948. In Russian.)

535.343.4:535.61-15 1348

The Infra-Red Spectra of Atmospheric Gases other than Water Vapour—G. B. B. M. Sutherland and G. S. Callendar. (*Rep. Progr. Phys.*, vol. 9, pp. 18–28; 1942 and 1943.)

535.343.4:535.61-15:546.212 1349

The Absorption of Water Vapour in the Far Infra-Red—T. G. Cowling. (*Rep. Progr. Phys.*, vol. 9, pp. 29–41; 1942 and 1943.)

536.3 1350

The Efficiency of Radiation Shields—A. E. De Barr. (*Rev. Sci. Instr.*, vol. 19, p. 922; December, 1948. Comment on 1022 of May (Garrison and Lawson).

537.122:538.3 1351

General Properties of the Paraxial Electron-Optic Image—F. Borgnis. (*Helv. Phys. Acta*, vol. 21, pp. 461–479; December 20, 1948. In German.) Discussion, for fields of axial symmetry, based on the differential equation for an electron path near the axis.

537.2 1352

Potential and Field of a Plane Electrode with an Elliptical Hole—M. Cotte. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 377–378; January 31, 1949.) Exact formulas are derived.

537.311.62 1353

Calculation of the Magnetic Skin Effect in Steel Sheets taking into account the Relationship between Magnetic Permeability and Magnetic Field Intensity—S. D. Margolin. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1306–1316; October, 1948. In Russian.)

537.311.62 1354

The Theory of the Anomalous Skin Effect in Metals—G. E. H. Reuter and E. H. Sondheimer. (*Proc. Roy. Soc. A*, vol. 195, pp. 336–364; December 22, 1948.) The problem of high-frequency metallic conduction is reviewed and exact solutions are obtained which are valid at all frequencies and temperatures. For large values of the free path of the conduction electrons, the electric field is propagated through the metal as a "surface wave" which differs considerably from the classical exponential solution. For the temperature variation of the surface impedance in the microwave range, Pippard's simplified theory is qualitatively correct. The frequency variation of the surface impedance at low temperatures is also discussed; relaxation effects are negligible in the microwave range but become important in the infrared and eventually restore the validity of the classical theory. Theory predicts that the reflection coefficient of metals should pass through a minimum in the far infrared. See also 1014 of 1948 (Pippard).

537.312.62 1355

Superconductivity—K. Mendelssohn. (*Rep. Progr. Phys.*, vol. 10, pp. 358–375; 1944 and 1945. Bibliography, pp. 375–377.) A general review, with particular reference to Russian and German work.

537.533:530.145.6:621.385.833 1356

Field Emission of Electrons—R. O. Jenkins. (*Rep. Progr. Phys.*, vol. 9, pp. 177–197; 1942 and 1943.) A survey of experimental work begins with that of Lilienfeld and includes the development of the field-emission electron microscope. The application of wave mechanics is discussed.

538.22 1357

Modern Theory of Magnetism: Part 2—S. V. Vonsovski. (*Uspekhi Fiz. Nauk*, vol. 36, no.1 pp. 30–82; 1948. In Russian.) Discussion of diamagnetic and paramagnetic materials and magnetic cooling.

538.3 1358

The Field of a Point Source of Current located on the Surface of the Earth above an Inclined Layer—I. P. Skal'skaya. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1242–1254; October, 1948. In Russian.)

538.3 1359

Classical Electrodynamics without Singularities—H. McManus. (*Proc. Roy. Soc. A*, vol. 195, pp. 323–336; December 22, 1948.) It is possible to construct a theory of the electron with an extended charge distribution in a Lorenz invariant way by introducing a 4-dimensional form function. Electromotive field quantities reduce to those given by the ordinary theory at distances large compared with the electron radius, but remain finite on the world line. See also 698 of 1948 (Eliezer).

538.6:537.525 1360

The Influence of a Transverse Magnetic Field on a Cylindrical Plasma—L. Beckman. (*Proc. Phys. Soc.*, vol. 61, pp. 515–520; December 1, 1948.)

621.39.001.11 1361

A Mathematical Theory of Communication—C. E. Shannon. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 379–423 and 623–656; July and October, 1948.) The methods of statistical mechanics are applied to determine rates for the efficient transmission of information in generalized coded forms. The properties of discrete and continuous sources and the effect of noise are considered. Entropy of the source and capacity of the channel are defined, and it is shown that statistical matching of channel to source is required. By suitable choice of coding, errors in transmission may be made as small as desired, provided the rate does not exceed the channel capacity. For a continuous

source, the maximum rate is expressed in terms of a measure of required fidelity.

621.396.822 1362

The Energy of Electrical Fluctuations in Conductors—E. Ya. Pumper. (*Zh. Eksp. Teor. Fiz.*, vol. 18, pp. 1112–1129; December, 1948. In Russian.) The limitations of Nyquist's formula (p. 1112) determining the thermal effect are discussed. Experiments were designed to determine the distribution of probabilities of electrical fluctuations in conductors at frequencies from 4 to 136 kc, and for the absolute measurement of fluctuational energy. The main conclusions reached are: (a) In many thin metallic and graphite conductors, the noise level exceeds the value calculated from the thermal effect theory; the discrepancy increases with the frequency. (b) Experiments with an electrolyte (a weak solution of KCl) and annealed resistances have shown that other variations, besides those due to thermal effect, occur more rarely and disturb the distribution of probabilities. (c) Experiments with heated resistances have shown that additional fluctuations can be eliminated by rapid annealing. (d) There are reasons to suppose that the excess of the fluctuation level over the theoretical value is due to emission of energy from the crystal lattice and is related to the process of crystallization.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

522.56:523.7 1363

Physical Basis of Solar Research and Technical Aids—V. von Keussler. (*Z. Angew. Phys.*, vol. 1, pp. 232–242; November, 1948.) A review, for the last 20 years, of research methods and apparatus for optical wavelengths. 72 references are included.

523.53:551.510.535 1364

The Exploratory Properties of Radio Waves and Their Application to the Detection of Meteor Trails—R. Naismith. (*Atti del Congresso internazionale della Radio* (Rome), pp. 160–167; September and October, 1947. In English.) The transient echoes observed near the sporadic-*E* region are due to reflections from the ionization trails of meteors. There is a marked seasonal variation in the number of meteors recorded around noon. The response of the medium also has a seasonal variation. In temperate latitudes, sporadic-*E* ionization is mainly due to the fine dust of meteors. The atmosphere is continually being bombarded with meteoric dust particles, most of which are too small to produce visible meteor trails.

523.53:621.396.9 1365

The Theory of the Radio Detection of Meteors—Manning. (*See* 1392).

523.72:523.854 1366

The Radio Spectrum of the Sun and of the Milky Way—C. E. Krüger. (*Atti del Congresso internazionale della Radio* (Rome), pp. 133–140; September and October, 1947. In Italian.) Discussion and theoretical interpretation of results obtained by various authors. See also 1028 of 1945 (Reber) and 3270 of 1946 (Hey, Parsons, and Phillips).

523.72+523.854]:621.396.822 1367

Radio Astronomy—C. R. Burrows. (*Electronics*, vol. 22, pp. 75–79; February, 1949.) A general review of knowledge obtained from solar and galactic rf radiation measurements, and of possible future developments.

523.72.029.62 1368

Some Characteristics of Solar Radio Emissions—J. S. Hey, S. J. Parsons, and J. W. Phillips. (*Mon. Not. R. Astr. Soc.*, vol. 108, no. 5, pp. 354–371; 1948.) Continuation of experimental investigations noted in 1825 of 1946 (Hey) and 3508 of 1947 (Appleton and Hey). Discussion of the relation between solar radio emissions observed mainly at $\lambda = 4.1$ meters between March, 1946 and September 1947, and associated visual solar and geophysical phenomena. The most intense flares are the most likely to produce radio bursts; in general, the radio emission lags several minutes behind the visual or ultra-violet flare radiations. The heliographic distribution of coincidences between flares and bursts is considered and contrasted with the sharply beamed pattern of continuous radiation associated with sunspots.

523.745:550.385/.386 1369

Geomagnetic Disturbances and Solar Activity—A. I. Ol'. (*Priroda*, pp. 3–10; July, 1948. In Russian.) Discussion of corpuscular solar radiation and its connection with disturbances of the earth's magnetic field, with special reference to the solid angle of the radiation, the "M-regions" in the sun which emit the radiation, observations of the absorption lines of ionized Ca in the solar spectrum during magnetic storms, and the two types of corpuscular radiation thought to cause the two classes of magnetic storms.

523.746:550.38 1370

Observational Aspects of the Sunspot-Geomagnetic Storm Relationships—H. W. Newton. (*Mon. Not. R. Astr. Soc.*, vol. 108, no. 5, p. 423; 1948.) Summary only. Using international magnetic character figures, the statistical rise of geomagnetic activity is investigated for the solar disk passage of four area groupings of sunspots, between 1914 and 1944. For large sunspots, there is an increase of geomagnetic activity centered at about 2 days after the central meridian passage of the sunspots. For smaller sunspots, groupings based on solar flare incidence are better correlated with geomagnetic activity than those based on area. 27-day recurrence tendencies of geomagnetic activity are not well defined except in the case of the smaller storms, especially those without associated sudden commencements, sunspots, or solar flares. The statistical nonrecurrence of great magnetic storms is confirmed.

523.746 "1941" 1371

Mean Areas and Heliographic Latitudes of Sunspots in the Year 1941—(*Mon. Not. R. Astr. Soc.*, vol. 108, no. 5, pp. 420–422; 1948.)

523.746.5 1372

Double Cycle of Solar Activity—A. I. Ol'. (*Priroda*, pp. 39–41; August, 1948. In Russian.) Additional confirmation of the existence of the 22-year cycle of solar activity suggested by M. N. Gnevyshev and A. I. Ol'. (*Astronomicheski Zhurnal*, vol. 25, no. 1. 1948. In Russian.)

523.76 1373

Solar Physics—A. Hunter. (*Rep. Progr. Phys.*, vol. 9, pp. 101–112; 1942 and 1943.)

538.12:521.15 1374

Magnetic Field of Massive Rotating Bodies—Yu. G. Pliner. (*Priroda*, pp. 16–24; July, 1948. In Russian.) The implications of Blackett's theory (3112 of 1947) are discussed and the following three methods of its verification are considered in turn: (a) application of the theory to stars, (b) extension of the theory to rotating bodies on the earth, and (c) extension of the theory to elementary particles such as Bohr's magnetron. The possibility is suggested that the magnetic field of the moon could be measured by means of rockets which would overcome the force of gravity of the earth and be attracted by the moon while sending radio messages back to the earth. Experiments conducted by P. N. Lebedev in 1909 are mentioned in connection with (b).

551.5:621.396 1375

Applications of Radio in Modern Meteorology—R. Bureau. (*Atti del Congresso internazionale della Radio* (Rome), pp. 683–695; September and October, 1947. In French.) Various radio techniques have combined to increase enormously the quality and quantity of information available for the forecaster.

551.51:541.14 1376

Photochemical Processes in an Oxygen-Nitrogen Atmosphere—C. H. Bamford. (*Rep. Progr. Phys.*, vol. 9, pp. 75–89; 1942 and 1943. Bibliography, pp. 89–91.)

551.51:541.14:546.21 1377

The Photochemistry of Atmospheric Oxygen—S. Chapman. (*Rep. Progr. Phys.*, vol. 9, pp. 92–100; 1942 and 1943.) An outline of the attempts made to account for the existence of ozone and atomic oxygen. The diurnal and seasonal changes in the ozone content of the atmosphere are discussed.

551.510.5:537.56 1378

Ionization Phenomena in the Earth's Atmosphere—J. Sayers. (*Rep. Progr. Phys.*, vol. 9, pp. 52–61; 1942 and 1943.) For the first 20 km above sea level the ionization balance is simple and measurements of conductivity confirm the theoretical values. The balance equations for free electrons and for ions in the ionosphere are developed. The effective recombination coefficients for the *E* and *F* regions are discussed and compared with values deduced from radio observations.

551.510.5:546.21 1379

The Properties of Neutral and Ionized Atomic Oxygen and their Influence on the Upper Atmosphere—H. S. W. Massey and D. R. Bates. (*Rep. Progr. Phys.*, vol. 9, pp. 62–74; 1942 and 1943.) The energy levels of positive and negative ions and neutral atoms of oxygen are briefly considered and the probabilities of various ionization, recombination, and attachment processes are discussed. In the ionosphere, the observed recombination coefficients are too large to be accounted for by direct radiative recombination of electrons and ions; the presence of negative ions must be assumed.

551.510.535 1380

The Present State of Investigations of the Ionosphere: Part 2—Ya. L. Al'pert. (*Uspekhi Fiz. Nauk*, vol. 36, no. 1, pp. 1–29; 1948. In Russian.) The formation of ionized layers and the processes taking place in them are discussed.

551.510.535 1381

The Analysis of Ionospheric Reflections: Part 1—A. H. de Voogt. (*Tijdschr. ned. Radiogenoot.*, vol. 13, pp. 83–195; November, 1948. In English. Corrections, *ibid.*, vol. 14, January, 1949; insert.) Formulas for the complex refractive index and polarization are based on the Appleton-Hartree formula; curves are given representing the results of careful calculations, by the mathematical bureau of the Dutch Post Office, of refractive index, group velocity, attentuation, and polarization for a frequency of 6 Mc, assuming conditions similar to those over the Netherlands. Experiments to verify these results will be described in part 2.

551.510.535:525.624 1382

The Lunar Atmospheric Tide at Twenty-Seven Stations Widely Distributed over the Globe—S. Chapman and K. K. Tschu. (*Proc. Roy. Soc. A*, vol. 195, pp. 310–323; December 22, 1948.) The tides were determined by the Chapman-Miller method from bi-hourly values of barometric pressure covering periods of 5 years or more at each station. Results are discussed.

551.510.535:621.317.79 1383

Ionosphere Reflections Recorded Mechanically by Means of a Repetition Frequency Converter—Stoffregen. (*See* 1438.)

551.510.535:621.396.11 1384

Regular Ionosphere Observations over Mid-Germany—Dieminger. (*See* 1475.)

551.510.535:621.396.11 1385
Ionosphere Review: 1948—T. W. Bennington. (*Wireless World*, vol. 55, pp. 56–60; February, 1949.) A survey of sunspot and short-wave propagation conditions for 1948, with forecast for 1949.

551.593.9 1386
The Spectrum of the Night Sky—R. W. B. Pearse. (*Rep. Progr. Phys.*, vol. 9, pp. 42–51; 1942 and 1943.)

551.593.9 1387
Variations of the Colour of the Night Sky from March 1947 to May 1948—R. Grandmontagne and C. Delestrade. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 415–416; January 31, 1949.) Results obtained with a photoelectric recorder at the Haute-Provence observatory are tabulated and discussed.

551.594 1388
Electric Field Intensity Inside of Natural Clouds—R. Gunn. (*Jour. Appl. Phys.*, vol. 19, pp. 481–484; May, 1948.) Maximum intensities measured by instruments carried on aircraft flying through the clouds were of the order of 3 kv per centimeter. This is much higher than previous values based on free-balloon soundings. See also 2425 of 1947.

551.594.21 1389
Propagation of Atmospherics—H. Norinder. (*Atti del Congresso internazionale della Radio* (Rome), pp. 168–195; September and October, 1947. In English.) Discussion of initial results of a projected long-term investigation. Two mobile stations and a fixed station near Uppsala (Sweden) were almost in line, with intervals of 27 and 37 km. Numerous oscillograms of the received electric field are shown; a striking feature is a change of polarity beyond a certain distance, which may partly be due to reflection from ionized layers at a great height in the thunderstorm. Simultaneous observations of atmospherics at two fixed stations 200 km apart are also discussed; the importance of direction finders at these stations is emphasized. See also 3907 of 1947 and back references.

551.594.21:621.396.11 1390
Guided Propagation of Radar in Thunderstorm Conditions—Coons. (*See* 1478.)

551.594.221 1391
The Lightning Discharge—J. M. Meek and F. R. Perry. (*Rep. Progr. Phys.*, vol. 10, pp. 314–354; 1944 and 1945. Bibliography, pp. 354–357.) The formation of thunderclouds and the mechanism of the lightinng discharge are discussed from the theoretical aspect and accounts of experiments using a Boys' camera are given. The technique of the measurement of the current and voltage of a discharge is considered generally. An electrometer to measure atmospheric voltage gradients is described and results obtained with it are given. Future work is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.9:523.53 1392
The Theory of the Radio Detection of Meteors—L. A. Manning. (*Jour. Appl. Phys.*, vol. 19, pp. 689–699; August, 1948.) Methods of observation for both bursts of signal strength and whistles caused by reflection of radio waves from meteoric ionization are discussed. Meteor velocity and range can be accurately determined by combined burst and whistle observations. The possibility of determining the direction and position of a meteor path by observations at 3 receiving stations is examined. The percentage of meteors capable of producing bursts depends on the angle between the meteor path and the vertical and on the direction from which signals are received; various possible formulas for it are discussed.

621.396.93 1393
Recent Progress in Radio Direction Finding—R. L. Smith-Rose. (*Atti del Congresso internazionale della Radio* (Rome), pp. 877–901; September and October, 1947. In English.) A detailed survey of methods used in the frequency range 10 kc to 1,200 Mc. Antenna systems, recent advances in instrumental technique and calibration, accuracy limitations, and the effect of the ionosphere on the accuracy of bearings are discussed. Methods of direction-finding transmission include the rotating-loop beacon, the equi-signal beacon and the Consol system. Future trends in high-frequency direction finders include the use of highly directional receiving systems for the reduction of site errors, more accurate transfer of angular data from the direction finder to the plotting center, and methods to enable the operator to assess the approximate bearing accuracy.

621.396.93 1394
Automatic Direction-Finder—J. R. Steinhoff. (*Electronics*, vol. 22, pp. 97–99; February, 1949.) A light-weight and compact instrument having bearing accuracy within 1°. The externally mounted loop assembly is stationary and hermetically sealed; it consists of 4 coils arranged as two pairs at right angles. A special switching system enables each coil voltage to be sampled in succession 50 times a second and transmitted to the corresponding coil of the indicating meter, which is calibrated in degrees. Block and circuit diagrams are included.

621.396.93 1395
The Interconnection of Dead-Reckoning and Radar Data for Precision Navigation and Prediction—B. Chance. (*Jour. Frank. Inst.*, vol. 242, pp. 355–372; November, 1946.) The importance of accurate dead-reckoning data for both ship and aircraft navigation is stressed. Methods of providing an index on a radar display which continuously indicates the dead-reckoning position of an identifiable object are discussed. The solution of problems involving the relative motion of two ships, wind velocity, or ground range in antenna navigation can thus be greatly simplified. See also 1396 below.

621.396.93 1396
G.P.I. [ground position indicator]—An Automatic Navigational Computer—W. J. Tull and N. W. MacLean. (*Jour. Frank. Inst.*, vol. 242, pp. 373–398; November, 1946.) A device indicating continuously the present position on the earth's surface of the ship or aircraft in which it is carried. Wind velocity and velocity relative to the ground are determined from data provided by a true air-speed meter and the radar and compass. The total distance traveled is presented numerically and the heading required in order that a particular course may be followed is also indicated. The computing mechanism used is described in detail and its operation is explained. The main types of error due to the instruments which supply the GPI with data are discussed. Applications are considered. See also 1395 above.

621.396.93:621.396.67 1397
An Investigation of Resonances and Asymmetry in the Adcock Aerial Systems—Fradin and Khatskelevich. (*See* 1293.)

621.396.932 1398
Radar for Tilbury-Gravesend Ferry—(*Engineer* (London), vol. 186, p. 595; December 10, 1948.) Scanner unit 80 feet above ground; frequency 9,425 to 9,525 Mc; output power 30 kw; pulse width 0.2 microsecond and repetition rate 2,000 pulses per second; 2-way radio telephone communication between the radar operators and the masters of the ferries; PPI display with ranges of 0.8, 1.2, or 3 miles.

621.396.933 1399
Review of Recent Trends in Radio Aids to Air Navigation—H. Busignies, P. R. Adams, and R. I. Colin. (*Atti del Congresso internazionale della Radio* (Rome), pp. 696–716; September and October, 1947. In English.) A comprehensive account of basic principles and development work, with a brief description of various existing systems. International recommendations are summarized.

621.396.933 1400
Aerial Radio Navigation in Wartime—Guigonis. (*Onde Élec.*, vol. 29, pp. 21–25; January, 1949.)

621.396.933 1401
Decca Navigator System of Hyperbolic Navigation—P. Giroud and L. Couillard. (*Onde Élec.*, vol. 29, pp. 5–20; January, 1949.) A detailed discussion of basic principles, method of operation, practical equipment, and applications.

621.396.933.2 1402
High-Stability Radio Distance-Measuring Equipment for Aerial Navigation—H. Busignies. (*Elec. Commun.* (London), vol. 25, pp. 237–243; September, 1948.) A performance specification with brief technical description of a 51-channel interrogator-responder system. Challenging and responding frequencies, which are crystal controlled, are separated by 125.5 Mc; both are in the antenna-navigation band of 960 to 1,215 Mc. Adjacent channels may be used by different beacons, and one beacon can deal with up to 50 aircraft. Distances up to 100 nautical miles are indicated on a meter with an accuracy within ± 0.2 mile or 1 per cent whichever is the greater.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 1403
On High-Vacuum Technique—G. W. Oetjen. (*Elektrotechnik* (Berlin), vol. 2, pp. 333–340; December, 1948.) A review of modern methods and equipment, with particular reference to pumping rates, the different oils used in oil diffusion pumps, high-vacuum tubes, gauges, etc.

535.37 1404
The Relation between Efficiency and Exciting Intensity for Zinc-Sulfide Phosphors—H. A. Klasens, W. Ramsden, and Chow Quantie. (*Jour. Opt. Soc. Amer.*, vol. 38, p. 649; July, 1948.) Corrections to 3422 of 1948.

535.37:621.385.832 1405
Silicate Phosphors for Cathode Ray Tubes—P. N. Campbell. (*Jour. Soc. Chem. Ind.* (London), vol. 66, pp. 191–194; June, 1947.) The object of the experimental work described was to produce a phosphor which would give a white screen suitable for television. A mixture of powders to produce the correct color has been found but the brilliance is not yet satisfactory. Possible future developments are indicated. "Settling" is thought to be the most effective and economical method of preparing screens on a large scale.

537.228.1 1406
Recent Progress in Piezoelectric Technique—A. Tournier. (*Atti del Congresso internazionale della Radio* (Rome), pp. 485–518; September and October, 1947. In French.) An illustrated account of the production of quartz crystals from silica at the Laboratoire Central de Télécommunications. Crystallization of other salts can be accelerated by rotation of the crystal during formation and by addition of crystal impurities. Piezoelectric characteristics of rochelle salt and other crystals are discussed in detail. Certain phosphates and arsenates of ammonium or potassium can be used to obtain directly a bandwidth of 4 kc at a carrier frequency of 80 kc, but they have a large characteristic impedance and

temperature coefficient of frequency. See also 2811 of 1948.

538.13+538.221 1407

The Magnetic After-Effect of Different Types of Silicon-Iron—H. Wilde and G. Bosse. (*Frequenz*, vol. 2, pp. 214–215; August, 1948.) The effect of temperature and of frequency on the complex permeability of three grades of material, containing respectively 4 per cent, 3.5 per cent, and 2.5 per cent Si, is shown graphically. Curves are also given for the permeability for various ac fields.

538.221 1408

Some New Ferromagnetic Manganese Alloys—F. A. Hames and D. S. Eppelsheimer. (*Nature* (London), vol. 162, p. 968; December 18, 1948.) The results of an investigation on three Cu-Mn-Ga alloys are given. Two specimens were strongly magnetic when quenched from 750° C. X-ray diffraction data are tabulated, but cannot as yet be satisfactorily interpreted.

538.221:538.213 1409

Ferro-Magnetics at Ultra-High-Frequencies—M. J. O. Strutt. (*Atti del Congresso internazionale della Radio* (Rome), pp. 448–459; September and October, 1947. Bibliography, pp. 459–462. In English.) It seems probable that in the range of very low frequencies (from zero to a few kc) the effective permeability declines from several thousand to several hundred for certain very pure ferromagnetic materials. Anomalies found by some experimenters near 3 Mc are believed to be spurious. At room temperatures, a marked decline from several hundred to about unity occurs in the frequency range 300 to 30,000 Mc; it is suggested that the increased conductivity at low temperatures would have the same effect as a corresponding increase of frequency. Even slight differences in treatment of a well-defined material may result in large differences in measured permeability values; hence the entire range 0 to 30,000 Mc should be investigated in one laboratory. A theoretical explanation of the fall in permeability is given in terms of eddy-current effects.

538.244 1410

Magnetization in Perpendicularly Superposed Direct and Alternating Fields—F. J. Beck and J. M. Kelly. (*Jour. Appl. Phys.*, vol. 19, pp. 551–562; June, 1948.) General investigation of the behavior of an iron specimen. Curves of the dynamic longitudinal magnetic induction versus transverse magnetic field intensity and transverse magnetic induction are included.

621.315.59 1411

Properties of Poorly Conducting Layers between Metals and Semiconductors—V. E. Lashkarev. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1347–1355; November, 1948. In Russian.)

621.315.59:621.314.63 1412

Rectification at the Boundary of Two Semiconductors—A. V. Ioffe. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1498–1510; December, 1948. In Russian.) A detailed report upon an experimental investigation. For rectification, the two semiconductors in contact must have different types of conductivity and there must be a difference of contact potentials. The hole contact potential should be higher than the electron potential. The following processes are also of importance in rectification: (a) the formation of barrier layers of low conductivity, (b) variations in their thickness during the passage of the current, (c) increase in the conductivity of semiconductors under the influence of the electric field, and (d) transfer of charges through the boundaries of the semiconductors.

621.315.612 1413

New Ceramic Materials with Very High Dielectric Constant—A. Pascucci and H. Wolf-Stawski. (*Atti del Congresso internazionale della Radio* (Rome), pp. 336–363; September and October, 1947. In Italian.) The work of various authors is reviewed and an experimental investigation into the relationship between dielectric constant and loss angle for materials containing titanates of Ba and Sr is described. Applications are discussed.

621.315.612.011.5 1414

Variation of the Dielectric Properties of Ceramic Materials with Magnesium-Orthotitanate Base and Its Representation by the Logarithmic Law of Mixtures—E. Albers-Schoenberg and W. Soyck. (*Ann. Radioélec.*, vol. 3, pp. 290–292; October, 1948.) Results for materials containing titanates of Mg and Ca or Sr show the logarithmic law to hold for the dielectric constant, which increases from about 20 for 7 per cent of $CaTiO_3$ to 120 for 85 per cent of $CaTiO_3$, the corresponding temperature coefficients being -10×10^{-6} per °C and $-1{,}600\times10^{-6}$ per °C.

621.318.2 1415

Permanent Magnets—W. E. Burnand. (*Elec. Rev.*, (London), vol. 144, pp. 63–67; January 14, 1949.) Discussion of economical methods of magnetization for magnets of awkward shapes.

621.318.22 1416

Materials for Permanent Magnets—S. Wintergerst. (*Funk und Ton*, vol. 3, pp. 48–50; January, 1949.) The composition and some magnetic and physical properties of 12 alloys are tabulated and discussed.

621.318.22 1417

Magnetic Materials: a Review of Progress—F. Brailsford: D. A. Oliver and D. Hadfield: G. R. Polgreen. (*Jour. IEE* (London), part I, vol. 95, pp. 522–543; December, 1948.) Part 1: Electrical sheet steels. Part 2: Permanent magnet materials. Part 3: Magnetic powder cores.

621.775.7:538.221 1418

Verification of Néel's Theory for the Coercive Field of Finely Powdered Ferronickel Alloys—L. Weil. (*Compt. Rend. Acad. Sci.* (Paris), vol. 227, pp. 1347–1349; December 20, 1948.) Measurements on alloys containing 50 to 90 per cent Ni confirm that the mean coercive field for agglomerated powders with little or no magnetic anisotropy is directly proportional to the magnetization at saturation. See also 3151 and 3152 of 1947 (Néel).

666.1.037.5 1419

The Theory of Stresses in Two-Component Glass to Metal Tube Seals—H. Rawson. (*Jour. Sci. Instr.*, vol. 26, pp. 25–27; January, 1949.) Theory based on that of Lamé is given, with curves showing the dependence of the principal stresses at the seal interface on the seal dimensions.

666.192.037.5 1420

New Quartz-Metal Seal—E. H. Nelson. (*Elec. Rev.* (London), vol. 144, pp. 60–62; January 14, 1949.) The metal part of the seal consists of a Mo annulus of lenticular cross section soldered coaxially upon a Mo rod. The rod provides a large current-carrying capacity whilst the annulus gives a hermetic seal.

679.5:535.316/.317:534.321.9 1421

Ultrasonic Lenses of Plastic Materials—D. Sette. (*Jour. Acous. Soc. Amer.*, vol. 21, p. 61; January, 1949.) Summary of Acoustical Society of America paper. Propagation velocity and attenuation of elastic waves have been measured in various synthetic materials; plexiglas appears to be the most suitable material for such lenses.

MATHEMATICS

517.53:621.392.52 1422

Splitting of an Analytical Function into a Linear and a Nonlinear Part, and also a Method of Determining, for a Known Linear Component, the Nonlinear Component and the Function as a Whole—H. Pleijel. (*Arch. Elek.* (Übertragung), vol. 2, pp. 307–320; August and November, 1948.) Mathematical discussion. In many cases, the problem has a simple solution. Applications to the theory of filter networks are considered.

517.942:621.396.611.3 1423

On Linear Differential Equations with Slowly Variable Coefficients. Application to the Study of Nonlinear Coupling—C. Blanc. (*Bull. Tech. Suisse Romande*, vol. 74, pp. 185–188 and 209–213; July 17, and August 14, 1948.) For an equation with slowly variable coefficients and such that the integrals of the equation with the right-hand side replaced by zero tend sufficiently rapidly toward zero when the independent variable increases indefinitely, a solution is obtained involving a function which plays the part of a variable admittance. This result is applied to discussion of the maintenance of the oscillations of a pendulum by ac, and also to the case of two circuits coupled by the variable capacitance between two plates linked elastically.

517.942.1:518.5 1424

Electro-Integrator for the Solution of the General Linear Differential Equation with Constant Coefficients—N. V. Korol'kov and G. K. Kuz'minok. (*Bull. Acad. Sci.* URSS, pp. 517–532; April, 1948. In Russian.) The device described solves systems of such differential equations with a speed determined only by the duration of the transient process in the circuit; any relevant dynamic conditions can be simulated. The integrator is based on a circuit proposed by L. I. Gutenmacher and consisting of a number of interconnected two-terminal and four-terminal networks (tube amplifiers). The solution obtained is shown on a cro or a loop (mechanical) oscillograph and can be photographed. The operation of the integrator is discussed in detail. A year's experience has proved its suitability for many kinds of research work.

518.5 1425

A Discussion on [general-purpose, automatic, digital] Computing Machines—(*Proc. Roy. Soc. A*, vol. 195, pp. 265–287; December 22, 1948.) The following papers were read: A Historical Survey of Digital Computing Machines, by D. R. Hartree. General Principles of the Design of All-Purpose Computing Machines, by M. H. A. Newman. The Design of a Practical High-Speed Computing Machine, the EDSAC, by M. V. Wilkes. A Cathode-Ray Tube Digit Store, by F. C. Williams. The Automatic Computing Engine at the National Physical Laboratory, by J. H. Wilkinson. Recent Computer Projects, by A. D. Booth. See also 1157 and 1493 of 1947, 464 and 3448 of 1948, 759 of April and 1110 of May.

517.432.1 1426

Modern Operational Calculus, with Applications in Technical Mathematics [Book Review]—N. W. McLachlan. Macmillan, London, 1948, 218 pp., 21s. (*Nature* (London), vol. 162, p. 945; December 18, 1948.) Based on a transform simply related to that of Laplace. The book is intended for post-graduate engineers and technologists and is unusually rigorous.

MEASUREMENTS AND TEST GEAR

531.761+621.317.361 1427

Limits for the Comparison of Frequency and Time at Great Distances—M. Boella. (*Atti del Congresso internazionale della Radio* (Rome), pp. 213–224; September and October, 1947. In Italian.) A series of measurements on the stability of standard signals received from the Bureau of Standards confirms that irregular variations up to ±2 parts in 10^7 exist and are due to a propagation effect; their magnitude depends on the time of day. The afternoon is

the best time for precise comparisons at 15 Mc, the maximum errors then observed are 2 parts in 10^8. See also 1163 of May (Rawer) and back reference.

531.761 1428

High-Precision Comparison of Times—C. Egidi. (*Atti del Congresso internazionale della Radio* (Rome), pp. 292–296; September and October, 1947. In Italian.) Discussion of apparatus specially designed for comparing WWV with other standard signals.

621.317.3 1429

An Experimental Method for Determining the Fundamentals and Harmonics of Stationary Low-Frequency Electrical Quantities—F. Koppelmann. (*Frequenz*, vol. 2, pp. 296–303; November, 1948.) A moving-coil instrument is used with a mechanical rectifier (synchronized with the supply voltage) and suitably connected resistors to obtain the integral curve of the quantity in question. The values of the fundamental and harmonics are then calculated from measurements of selected ordinates. The method is illustrated by results for a transformer core.

621.317.324† 1430

Production of a Uniform H.F. Field for Measurement Purposes—E. Roeschen. (*Funk und Ton*, vol. 3, pp. 18–32; January, 1949.) Sensitive methods of field-strength measurement are based on measurements of mutual inductance. Curves are given showing the field strength for single circular coils and for combinations of pairs of coils. For a particular 4-coil system, the deviations from uniformity of the field were <1 per cent.

621.317.335.3†+621.317.374 1431

Determination of Dielectric Quantities by Balance Methods—T. Gast and E. Alpers. (*Z. Angew. Phys.*, vol. 1, pp. 228–232; November, 1948.) The basic principles of the methods are outlined and the apparatus used is described. Typical results are given showing the dependence of the dielectric constant and loss factor of polyvinyl chloride on temperature and frequency.

621.317.335.3†:546-145 1432

On the Measurement of the Dielectric Constant of Solutions at High Frequencies—U. Tiberio. (*Atti del Congresso internazionale della Radio* (Rome), pp. 463–484; September and October, 1947. In Italian.)

621.317.335.3†:621.392.26† 1433

Universal Curves for Dielectric-Filled Wave Guides and Microwave Dielectric Measurement Methods for Liquids—W. H. Surber, Jr. (*Jour. Appl. Phys.*, vol. 19, pp. 514–523; June, 1948.) A method is given for constructing a set of curves for the variation of waveguide parameters in terms of D, a dissipation factor of the dielectric filling analogous to $\tan\delta$ for coaxial lines. An experimental method is described for measuring the dielectric constant ϵ of a high-loss liquid contained in a waveguide, from the variation of reflection coefficient with sample length. The constants of the medium can then be determined using ϵ and D as primary independent parameters.

621.317.335.3†:621.396.611.4 1434

A Method for Measuring the Complex Dielectric Constant of Gases at Microwave Frequencies by Using a Resonant Cavity—C. K. Jen. (*Jour. Appl. Phys.*, vol. 19, pp. 649–653; July, 1948.) For low-pressure gases at X-band frequencies (8,500 to 9,750 Mc). The real part of the dielectric constant of a gas affects the natural frequency of a resonant cavity containing it, while the imaginary part affects the amplitude and breadth of the cavity response curve. By rapid variation of the frequency through resonance, the real and imaginary parts can be conveniently and accurately determined from cro measurements. Sample results are given. The method can also be used for the measurement of (a) the resonant dispersion and absorption of microwaves by gas molecules, and (b) the loaded and unloaded Q of a cavity.

621.317.725:621.317.733 1435

Analysis of Bridge-Type Valve Voltmeters— P. Popper and G. White. (*Wireless Eng.*, vol. 25, pp. 377–384; December, 1948.) Two arms of the bridge are formed by the tube and its associated resistors. The other two can be formed either by two resistors or by a similar tube and a resistor. These two types of bridge can be further subdivided according as the tube resistor is placed in the plate or cathode circuit. The relative merits of these four types are compared from the points of view of sensitivity, stability, linearity, and the effect of choice of output meter upon performance. For a single-tube circuit (with positive biasing battery) the transfer of the resistor from the plate to the cathode lead improves stability and linearity, but with the two-tube circuit this is not the case. A graphical solution for nonlinear operation in the two-tube circuit is given. Optimum deflection sensitivity occurs when the meter resistance equals the output resistance of the circuit; this cannot be realized in practice when plate resistors are used in double-tube circuits.

621.317.727 1436

An A.C. Potentiometer—J. M. Vanderleck. (*Elec. Eng.*, vol. 67, pp. 173–181; February, 1948.) Description of an instrument of the Gall type for general measurements. Simplicity of operation rather than absolute accuracy was the primary consideration.

621.317.761:621.396.611.4 1437

Electrical Measurements on Transmission Cavity Resonators at 3 cm Wavelength—M. S. Wheeler. (*Atti del Congresso internazionale della Radio* (Rome), pp. 520–525; September and October, 1947. In English.) Energy from a 3-cm FM oscillator is applied, through a variable attenuator and the cavity under test, to a rectifier crystal which provides, after amplification, the voltage for the vertical deflection of a cro beam. A small part of the oscillator energy is transmitted through a high impedance to another crystal, to which a standard frequency is also applied. The difference-frequency voltage intensifies the trace on the cathode-ray screen whenever the difference frequency falls within the pass band of the Z-axis amplifier. The horizontal sweep is derived from the oscillator modulating voltage, so that a response versus frequency curve is produced with bright spots superimposed and spaced equally on either side of the reference frequency. Accuracy of measurement of the resonance frequency is estimated as within 1 part in 150,000.

621.317.79:551.510.535 1438

Ionosphere Reflections Recorded Mechanically by Means of a Repetition Frequency Converter—W. Stoffregen. (*Jour. Appl. Phys.*, vol. 19, pp. 487–490; May, 1948.) The high repetition frequency (50 cps) of received ionospheric echoes is converted to a much lower frequency (0.2 to 0.5 cps) by a stroboscopic technique. Mechanical recording of echoes having a delay of some milliseconds, using a pulse width of 20 to 100 microseconds is thus facilitated. See also 789 of April.

621.319.4(083.74) 1439

Standards for Low Values of Direct Capacitance—C. Moon and C. M. Sparks. (*Jour. Res. Nat. Bur. Stand.*, vol. 41, pp. 497–507; November, 1948.) Discussion of the design and measurement of capacitors from 0.001 pF to 5 pF. Capacitors above 0.1 pF are of normal guard-ring type, but below this value a guard-well construction is used.

621.38/.39.001.4 1440

Transients in Mechanical Systems—J. T. Muller. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 657–683; October, 1948.) High-impact shock tests for electronic apparatus are analyzed by the Laplace transform for various types of impact pulse. Curves for the transient displacement and the maximum amplitude of the ensuing harmonic motion are given.

621.397.62.001.4 1441

Airline TV Receiver Installation Tests—W. S. Smoot. (*Communications*, vol. 29, pp. 8–9, 34; January, 1949.) A 12″ direct-viewing receiver was used, with alternative antennas above and below the aircraft. Power was supplied by means of an inverter. Performance on a run from Washington to Norfolk, Virginia, is discussed.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.001.82 1442

Generation of Sonic and Ultrasonic Waves in Liquids for Industrial Purposes—W. Janovsky and R. Pohlman. (*Z. Angew. Phys.*, vol. 1, pp. 222–228; November, 1948.) A special type of high-frequency whistle is described which gives frequencies from 4 to 32 kc and is very effective for the production of emulsions. The operating cost of emulsification by means of the whistle is about 0.003 of that when magnetostriction oscillators are used.

539.16.08 1443

Further Experiments with an Adjustable Geiger-Müller Counter—A. G. Fenton and E. W. Fuller. (*Proc. Phys. Soc.*, vol. 62, pp. 32–40; January 1, 1949.) Discussion of the effect of various counter variables on the occurrence of multiple pulses, and of the performance of the counter as an ionization chamber at operating potentials below the Geiger region. For earlier work see 2578 of 1948 (Chaudhri and Fenton).

539.16.08 1444

Recent Research on [Geiger-Müller] Counter Tubes—J. D. Craggs. (*Rep. Progr. Phys.*, vol. 9, pp. 137–155; 1942 and 1943. Bibliography, pp. 155–157.) The work done on the mechanism of counters since about 1938 is reviewed. The main sections deal with proportional and nonproportional counters and their absolute efficiency. Their application to the counting of visible photons, X-rays, and neutrons is discussed. Directional, discriminating, and other special types are briefly described.

539.16.08 1445

Two Methods of Measurement of Dead Time in Geiger-Müller Counters—J. L. Putman and E. H. Cooke-Yarborough. (*Jour. Sci. Instr.*, vol. 25, pp. 409–411; December, 1948.)

539.16.08:621.383 1446

Performance of 931-A Type Multiplier in a Scintillation Counter—G. A. Morton and J. A. Mitchell. (*RCA Rev.*, vol. 9, pp. 632–642; December, 1948.) The scintillation type of nuclear radiation detector uses such a multiplier to convert into an electrical pulse the light flash produced by a suitable phosphor crystal when it absorbs a nuclear particle. The main properties investigated are the number and distribution of spurious pulses generated by the multiplier in darkness and the pulse performance when very few photoelectrons contribute to the pulse.

620.179.16 1447

Supersonic Flaw Detectors—D. C. Erdman. (*Elec. Eng.*, vol. 67, pp. 181–185; February, 1948.) Echo techniques and apparatus.

621.38.001.8:621.3.012 1448

Handbook of Industrial Electronic Circuits [Book Review]—Markus and Zeluff. (*See* 1345.)

621.38.001.8:621.9 1449

The Application of Electronics to Machine Tools—(*Machinery* (London), vol. 73, pp. 663–668; November 11, 1948.) Discussion of

devices shown at the recent Machine Tools Exhibition at Olympia. In most cases, the number of electronic devices used has been kept to a minimum,and the circuit arrangements are designed for long life and ease of maintenance. Service requirements have stimulated the production of rugged, shock-proof, and moisture-proof components. Devices for obtaining stepless speed control, especially for small machines, were a prominent feature.

621.38.001.8:623.95 1450

Developments on Magnetic and Acoustic Mines at the Admiralty Mining Establishment—A. J. Baggott and C. H. Fawcett. (*Jour. IEE* (London), part I, vol. 95, pp. 550–551; December, 1948.) Discussion on 790 of 1948.

621.384.62† 1451

The Choice of Operating Mode for Standing Wave Type Linear Accelerators for Electrons—E. J. Lawton. (*Jour. Appl. Phys.*, vol. 19, pp. 534–539; June, 1948.)

621.384.62† 1452

Experimental Results on Standing Wave Type Linear Accelerators for Electrons—E. J. Lawton and W. C. Hahn. (*Jour. Appl. Phys.*, vol. 19, pp. 642–648; July, 1948.)

621.385.833 1453

Chromatic Aberration and Resolving Power in Electron Microscopy—E. G. Ramberg and J. Hillier. (*Jour. Appl. Phys.*, vol. 19, pp. 678–682; July, 1948.)

621.385.833 1454

Electron Microscopy—L. Marton. (*Rep. Progr. Phys.*, vol. 10, pp. 204–248; 1944 and 1945. Bibliography, pp. 248–252.) Magnetic lenses are discussed in some detail and formulas for focal length, magnification, chromatic and spherical aberration, and optimum aperture are given together with graphs showing their variation. Some experimental justification is given, and the superiority of magnetic over electrostatic lenses is shown. The theory of resolving power is not so well understood but there is experimental evidence for assuming a limit to resolution of about 20 Å for bright-field observation. For dark-field observation, the limit is somewhat larger. General descriptions are given of the main types of electron microscopes and allied instruments, and, in particular, of a microanalyzer and a microtome; the operational techniques involved are discussed.

621.385.833 1455

The Refractive Index in Electron Optics and the Principles of Dynamics—W. Ehrenberg and R. E. Siday. (*Proc. Phys. Soc.*, vol. 62, pp. 8–21; January 1, 1949.) A relation between the ray direction and the wave normal is obtained, and an expression for the optical path difference is given in terms of the magnetic flux enclosed. The results are applied to the differential equations for trajectories, the focusing properties of an axially symmetrical field and the interference pattern due to two converging bundles of rays enclosing a magnetic flux.

621.385.833 1456

Electron Lenses of Hyperbolic Field Structure: Part 2—R. Rüdenberg. (*Jour. Frank. Inst.*, vol. 246, pp. 377–408; November, 1948.) If the lens voltage is increased above the incident electron voltage, the beam is at first blocked. A further increase converts the lens into a curved mirror, the focal properties of which are analyzed. Boundary conditions which may be rigorously or approximately satisfied in actual designs are discussed, and the effects of lateral apertures and windows are considered in detail. Expressions are derived for various defects which are small and depend on only a few parameters of the lens field. The case of electron cylinder lenses is also considered. Part 1: 813 of April.

621.385.833 1457

Electron Lens Corrected for Spherical Aberration—P. Hubert. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 233–235; January 17, 1949.) The method of correction proposed consists in sending the electron beam through a narrow metal cylinder in order to use the attraction of the charges induced on the walls. Numerical calculations show that, with such a system, the resolving power is greatly improved. The method may have important applications in the case of the proton microscope.

621.385.833 1458

Electron Lens with Curvilinear Axis—P. Hubert. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228 pp. 302–304; January 24, 1949.) A magnetic lens with circular axis has been used by Svartholm and Siegbahn in the construction of a β-ray spectrograph (1868 of 1947). It is possible to construct a lens whose magnetic field does not possess rotational symmetry. The theory of such a system is given and the practical advantages are enumerated.

621.385.833:537.533:530.145.6 1459

Field Emission of Electrons—Jenkins. (*See* 1356.)

621.385.833.032.29 1460

On a New Electron Gun for High-Voltage Tubes—M. Bricka and H. Bruck. (*Ann. Radioélec.*, vol. 3, pp. 339–343; October, 1948.) Detailed description of a gun used on C.S.F. electron microscopes and diffraction analyzers. At 45 kv it gives a current density ten times that of the ordinary type of gun and has an efficiency of about 20 per cent. The high-voltage current is about 40 microamperes.

534.321.9.001.8:620.179.16 1461

Ultrasonic Material Testing and Other Applications [Book Notice]—B.I.O.S. Final Report No. 1679, Item No. 9 H.M. Stationery Office, London, 68 pp. plus reprints in German from various German journals. Many different workers had obtained suggestive results indicating the possibility of industrial application of ultrasonics to emulsification, precipitation, preparation of fine grain alloys, etc., but there was little evidence of actual use on an industrial scale. A magnetostriction technique was successfully used for both vertical and horizontal echo soundings. An ultrasonic glass delay line was also used in the Rehbock radar test set. Success in techniques for testing materials is claimed, though insufficient information is available as to the amount of material so tested. See also B.I.O.S. Final Reports Nos. 724 and 1504.

PROPAGATION OF WAVES

538.566 1462

On Formulae for the Principle of Huyghens for Electromagnetic Waves—F. Croze and É. Durand. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 236–239; January 17, 1949.) Formulas have been given by L. de Broglie (3083 of 1944) which are equivalent to those of Kottler but in which the elements of a surface wave have only superficial densities of current and electric and magnetic charges. Application of these formulas to the determination of the electric field in a secondary wave emanating from an element of a surface wave leads to formulas established by Love, Larmor, and Bromwich, so that de Broglie's formulas should be regarded as the correct expression of the principle of Huyghens, taken in its usual sense, for electromagnetic waves.

538.566 1463

On the Expression of the Principle of Huyghens for Electromagnetic Waves—F. Croze and P. Boillet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 305–307; January 24, 1949.) The formulas of Love, Larmor, and Bromwich for electromagnetic waves are derived directly from the classical formulas for the fields produced by electric and magnetic doublets. See also 1462 above (Croze and Durand).

538.566 1464

Generalized Magneto-Ionic Theory—N. C. Gerson and S. L. Seaton. (*Jour. Frank. Inst.*, vol. 246, pp. 483–494; December, 1948.) A vector equation relating the polarization of a homogeneous isotropic medium to the externally impressed magnetic field is derived for the case of a medium penetrated by an electromagnetic wave. The equation involves the fourth degree of the refractive index and is a generalization of that obtained by Booker (422 of 1939) for a 2-dimensional case.

538.566:551.510.535 1465

On the Polarization in the Ionosphere—J. Malsch. (*Arch. Elek.* (Übertragung), vol. 2, pp. 231–237; June and July, 1948.) Evidence from various sources is discussed which suggests that the so-called Lorentz term is not applicable in ionospheric propagation.

538.566.2 1466

Propagation of Electromagnetic Perturbations in an Atmospheric Waveguide—T. Kahan and G. Eckart. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 228, pp. 235–236; January 17, 1949.) An outline of the physical phenomena in an ideal plane atmospheric duct bounded by a perfectly conducting earth and a parallel plane at a height h where the index of refraction has a discontinuity. Mathematical theory will be published elsewhere. For low values of h, the field F of the dipole source at distance r varies as $1/r^3$, but above a limiting value of h/λ, $F \propto 1/\sqrt{r}$ and the energy is propagated in cylindrical waves of the TE type.

538.566.2 1467

Representation of the Radiation in an Atmospheric Duct by a Series of Virtual Sources—T. Kahan and G. Eckart. (*Compt. Rend. Acad. Sci.* (Paris), vol. 228, pp. 304–305; January 24, 1949.) Near the origin, the field in the duct can be derived by superposing, on the field of a dipole of double strength, the fields due to successive images of this dipole with respect to (a) the plane forming the upper boundary of the duct, and (b) the earth. This representation is valid up to a distance such that the ray from the first virtual image makes an angle with the horizontal at least equal to the angle of total reflection at the boundary layer. At greater distances, the field strength follows either the $1/r^3$ or the $1/\sqrt{r}$ law (see 1466 above).

621.396.1 1468

Diversity Reception in U.S.W. Radio Links—G. Barzilai and G. Latmiral. (*Wireless Eng.*, vol. 25, pp. 390–395; December, 1948.) The proper disposition of the receiving antennas is considered theoretically, taking account of the way in which they are connected to the receiver. Results are applied to a practical case.

621.396.11 1469

Coastal Refraction—T. L. Eckersley. (*Atti del Congresso internazionale della Radio* (Rome), pp. 97–110; September and October, 1947. In English.) The fact that the velocity of electromagnetic waves over land is less than their velocity over sea is inconsistent with Zenneck's surface-wave theory, but this theory is not considered relevant. The result can be obtained from pure diffraction theory. The difference in velocity (and, therefore, coastal refraction) is only significant at wavelengths between 15 and 1,500 meters.

621.396.11 1470

The Future of Wave Propagation Research—S. B. Smith and K. W. Tremellen. (*Atti del Congresso internazionale della Radio* (Rome), pp. 196–210; September and October, 1947. In English.) A survey of present knowledge and possible future developments for (a) atmospherics and extraterrestrial radiations, (b) vhf propagation (above 30 Mc) and superrefraction, (c) high-frequency propagation (3 to 30 Mc), (d) medium-frequency ground-wave propagation and ionospheric transmission

paths (0.15 to 3 Mc), (e) low-frequency propagation (10 to 150 kc).

621.396.11 1471
General Remarks on the Theory of Wave Propagation—H. Bremmer. (*Atti del Congresso internazionale della Radio* (Rome), pp. 30–42; September and October, 1947. In English.) Discussion of the effects of earth curvature, refraction and diffraction, and the relevance of both ray theory and mode theory.

621.396.11 1472
Mechanisms of Propagation—C. R. Burrows. (*Atti del Congresso internazionale della Radio* (Rome), pp. 43–51; September and October, 1947. In English.) Discussion of refraction, diffraction, and ionospheric and guided tropospheric propagation.

621.396.11 1473
Studies in Propagation—T. L. Eckersley. (*Atti del Congresso internazionale della Radio* (Rome), pp. 78–96; September and October, 1947. In English.) A critical survey. The properties of the ionosphere are discussed with reference to the problems of scatter clouds in the *E* layer, abnormal-*E*, and abnormal-*F*. Propagation over land and sea paths is discussed in some detail for $\lambda \leqq 10$ meters. The importance of the phase-integral method is stressed.

621.395.11:551.510.535 1474
A Note on the Phase Difference between Two Waves Reflected from the Ionosphere—J. M. Kelso. (*Jour. Appl. Phys.*, vol. 19, pp. 590–591; June, 1948.) Two relations given without proof by Appleton and Beynon (2895 of 1947) are discussed and shown to have wide validity.

621.396.11:551.510.535 1475
Regular Ionosphere Observations over Mid-Germany—W. Dieminger. (*Fernmeldetech. Z.*, vol. 1, pp. 222–224; November, 1948.) Diagrams show the diurnal variations of the monthly mean values of limiting frequency for the normal and abnormal *E* layers and for the F_2-layer ordinary component from January to October, 1948. Disturbances which occurred during October are briefly discussed.

621.396.11:551.510.535 1476
The Verification of Magneto-Ionic Theory from the Gyrointeraction of Radio Waves in the Ionosphere—M. Cutolo. (*Atti del Congresso internazionale della Radio* (Rome), pp. 65–77; September and October, 1947. In Italian.) Experimental results confirm V. A. Bailey's theory of gyrointeraction. The fact of gyrointeraction shows that there is an ionospheric resonance frequency in the sense indicated by Nicholls and Shelleng. A nocturnal variation was observed in the gyromagnetic frequency. The experimental methods discussed can be used to study the distribution of the earth's magnetic field in the ionosphere. See also 513 of 1947 (Cutolo, Carlevaro, and Ghergi) and 2055 of 1948.

621.396.11:551.510.535 1477
Measurement of the Parasitic Modulation in Gyrointeraction Phenomena—M. Cutolo and R. Ferrero. (*Alta Frequenza*, vol. 17, pp. 212–216; October, 1948. In Italian, with English, French, and German summaries.) An account of measurements on transmission paths between Turin and Taranto, Augusta and Palermo, with the Vatican transmitter as the interfering element. Curves show the variation of the parasitic modulation as a function of (a) the modulation frequency of the interfering station, and (b) time.

621.396.11:551.594.21 1478
Guided Propagation of Radar in Thunderstorm Conditions—R. D. Coons. (*Bull. Amer. Met. Soc.*, vol. 28, pp. 324–329; September, 1947.) Discussion of the behavior of radar echoes during thunderstorm conditions. A series of photographs of a PPI presentation shows the passage of storm clouds, and the abnormal range of ground echoes resulting from guided propagation caused by stratification of water vapor in the rain areas under the cloud.

621.396.11:621.396.619.13:621.396.65 1479
The Possibility of Transatlantic Transmission by Means of Frequency Modulation—Arguimbau and Granlund. (*See* 1506.)

621.396.81:621.397.5 1480
Field Test of Ultra-High-Frequency Television in the Washington Area—G. H. Brown (*RCA Rev.*, vol. 9, pp. 565–584; December, 1948.) A survey of the field strength of the signals from a broadcast transmitter operating in the 500-Mc band is described. The measurements were made at points along eight radial lines and also in about 50 homes with typical home receivers. From the results, the power required for satisfactory coverage was determined. Measurements in the homes were also made of the signal voltage for the existing 67.25-Mc television service and for transmissions on 505.25 Mc. Performances of various types of receiving antennas are compared. See also 3224 of 1948 (Brown, Epstein, and Peterson).

621.396.812.029.64 1481
A Method of Determining the Angle of Arrival—A. W. Straiton, W. E. Gordon, and A. H. LaGrone. (*Jour. Appl. Phys.*, vol. 19, pp. 524–533; June, 1948.) The angles of arrival of the direct and reflected rays are determined by measuring the phase difference for two points at different heights and the field strength at each point. Values obtained for 3-cm radiation over a 27-mile path are consistent with those calculated by ray theory, taking account of the refractive-index distribution deduced from meteorological measurements. See also 1182 of 1947 (Sharpless) and 1183 of 1947 (Crawford and Sharpless).

RECEPTION

621.396.1 1482
Diversity Reception in U.S.W. Radio Links—Barzilai and Latmiral. (*See* 1468.)

621.396.621 1483
On the Use of a Superregenerator in the Nonlinear Mode for the Reception of F.M. Signals—G. B. Ol'derogge. (*Radiotekhnika* (Moscow), vol. 3, pp. 76–87; November and December, 1948. In Russian.)

621.396.621:534.861 1484
The Acoustics of Broadcasting Receivers—Govyadinov. (*See* 1267.)

621.396.621:621.3.015.3 1485
Transient Response of an F.M. Receiver—M. K. Zinn. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 714–731; October, 1948.) The frequency detector is represented by two resonant impedances with low-frequency outputs in opposition. Mathematical treatment permits the calculation of the output voltage for rapid variation of the instantaneous frequency. Very large impulsive variations, resulting in abrupt changes of phase, such as may be produced by ignition interference, are analyzed and curves of output voltage are obtained. The method is also used to analyze the reception of a simple sinusoidal modulation; the signal-to-noise ratio is deduced for severe impulsive interference.

621.396.82:621.397.5 1486
The Effect of Aircraft on the Reception of Transmissions in the 45-Mc/s Band—R. A. Rowden and G. I. Ross. (*BBC Quart.*, vol. 3, pp. 251–256; January, 1949.) Reflection of radio waves from aircraft can have a disturbing effect upon vhf reception. Tests with random aircraft indicate that interference is serious only when the aircraft is within 6 miles of the receiver or within 3 miles of the line joining the transmitter and receiver. The fluctuations in field strength of horizontally polarized transmissions are three or four times as great as those with vertically polarized transmissions. Experiments with co-operating aircraft gave similar results.

621.396.822 1487
Report on the Present Limits of V.H.F., U.H.F. and S.H.F. Reception—M. J. O. Strutt. (*Atti del Congresso internazionale della Radio* (Rome), pp. 412–442; September and October, 1947. Bibliography, pp. 442–447. In English.) A review of various causes of unwanted rf noise, for frequencies between 30 and 30,000 Mc with discussion of (a) the admissible signal-to-noise ratio for various types of transmission and the present definition of noise figure, (b) thermal external noise, the antenna being regarded as enclosed in a space of dimensions large compared to λ, and in thermal equilibrium at the temperature of that space, (c) atmospheric and man-made noise, including the propagation of atmospherics, (d) ionospheric and extraterrestrial noise, with special reference to the temperature, location, and frequency bands of the various sources, (e) thermal fluctuations in resistive elements of a network, (f) tube and crystal noise, (g) low-noise circuits and methods of noise reduction, and (h) actual noise levels obtainable at the various frequencies.

621.396.822 1488
Noise in Linear Networks—E. J. Schremp. (*Atti del Congresso internazionale della Radio* (Rome), pp. 402–411; September and October, 1947. In English.) A mathematical analysis of the possible alternative representations of a passive or active linear network containing bilateral or nonbilateral elements. The results are applied mainly to thermal noise and various forms of shot noise in multi-electrode tubes.

621.396.822 1489
Thermal Noise Output in A.M. Receivers—M. V. Callendar. (*Wireless Eng.*, vol. 25, pp. 395–399; December, 1948.) Formulas given by Burgess for noise and signal outputs from rectifiers are examined, and criteria for the variation of signal-to-noise ratio with predetector bandwidth and signal input to the detector are shown graphically. Practical conclusions are given for television sound, telephony, and telegraphy receivers. See also 534 of 1948 (Thomas and Burgess).

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 1490
A Mathematical Theory of Communication—Shannon. (*See* 1361.)

621.391.63:534.321.9 1491
On the Modulation of Light at Radio Frequencies by means of Ultrasonic Waves—Giacomini. (*See* 1255.)

621.394/.395+621.315.2 1492
French Telecommunication Networks—J. Mailley; J. Gastebois. (*Câbles and Trans.*, (Paris), vol. 3, pp. 8–30; January, 1949. With English summary.) Developments from 1924 to 1949 of carrier-current, overhead, underground, and underwater cables are discussed and present-day local and long-distance telegraphy and telephony systems are described.

621.394/.395].724 1493
Repeater-Station Equipment—J. Malézieux and R. Sueur. (*Câbles and Trans.* (Paris), vol. 3, pp. 66–82; January, 1949. With English summary.) Review of developments since 1924, with special reference to standardization and carrier-current systems.

621.394/.395].74 1494
Maintenance of the Network of Long-Distance Underground Lines—R. Croze; A Chavigner. (*Câbles and Trans.* (Paris), vol. 3 pp. 106–133; January, 1949. With English summary.)

621.394/.395].74 1495
Electro-Mechanical Installations of the Amplification Centres of the [French] Long-Distance Cable Network—A. Romanet. (*Câbles*

and Trans. (Paris), vol. 3, pp. 83–95; January, 1949. With English summary.) A general description of the power supplies normally required at an amplification center, the operating conditions, and the evolution of suitable equipment, including batteries, rectifiers, voltage regulators, and generators.

621.394/.395].74 1496

The Future of the French Telecommunication Network—P. Marzin. (*Câbles and Trans.* (Paris), vol. 3, pp. 134–136; January, 1949. With English summary.)

621.395.44 1497

Carrier-Current Systems on Overhead Lines—R. Sueur. (*Câbles and Trans.* (Paris), vol. 3, pp. 96–105; January, 1949. With English summary.) A short account of various single- and multi-channel systems developed in France.

621.396 1498

Recent Developments in Radio Communication in Great Britain—M. Faulkner. (*Atti del Congresso internazionale della Radio* (Rome), pp. 752–787; September and October, 1947. In English.) A general account of some developments in the radio and allied services of the British Post Office. Details are given of point-to-point radio systems, alterations at pre-war stations, and post-war developments. A proposed radio-telephone terminal in N.W. London is to have initially at least 48 terminal equipments. The extension of single-sideband operation to long-distance point-to-point radiotelephone links is planned; the main features of the equipment are described. Results of laboratory tests with a fading machine (2299 of 1948) on the effect of propagation conditions are discussed and illustrated graphically. The relaying of television signals by balanced, coaxial, and unloaded telephone cables is considered and details are given of a special universal equalizer for quick reliable testing of video circuits. Plans are outlined for the extension of (a) outside broadcast networks in London, and (b) long coaxial-cable routes for transmission from the program source to distant service areas. The proposed method of relaying television signals by radio from London to Birmingham is described.

621.396.1:061.3 1499

International Telecommunication Convention, Atlantic City, 1947—P. E. Erikson. (*Elec. Commun.* (London), vol. 25, pp. 232–236; September, 1948.) Discussion of important changes or additions to the Madrid Convention of 1932. For other accounts see 1748, 1749, and 2357 of 1948.

621.396.3.029.56.58 1500

Multi-Channel Radio-Telegraph System for High-Frequency Circuits—T. E. Jacobi. (*RCA Rev.*, vol. 9, pp. 704–720; December, 1948.) Sub-carrier channels using FM in conjunction with single-sideband operation and space-diversity reception appeared from field tests to be the best of several systems tried; error rates of 0.02 to 0.14 per cent were obtained on a transcontinental circuit. Double-sideband circuits had high error rates during periods of selective fading; these could be reduced to the above values by using exalted-carrier receivers. Single-sideband systems make better use of the frequency band available and use the transmitter power more efficiently. Under present conditions of high-frequency congestion, reduction of bandwidth and increase of message capacity must be regarded as of paramount importance.

621.396.324 1501

Teleprinting over Radio Circuits—H. C. A. van Duuren. (*Atti del Congresso internazionale della Radio* (Rome), pp. 902–914; September and October, 1947. In English.) Description of a reliable telegraph circuit between Amsterdam and Batavia. Each letter is transmitted on a 7-unit code. When a fault is detected, the printer stops, a signal is given on the return path, and the transmitter is stepped back to the beginning of the faulty letter.

621.396.41:621.396.619.16 1502

Multiplex Radiotelephony Link between the Mainland and Corsica—P. Rivère. (*Ann. Radioélec.*, vol. 3, p. 338; October, 1948.) Corrections to 3508 of 1948.

621.396.5 1503

Radio for Telephone Service in America—H. I. Romnes. (*Atti del Congresso internazionale della Radio* (Rome), pp. 851–876; September and October, 1947. In English.) An account of methods used by the Bell System. A description of overseas radio telephone includes a world map of the direct and principal interconnecting services, existing and planned. Service to ships, a general mobile service, a domestic point-to-point system using the 30 to 300-Mc band, and a microwave relay system between New York and Boston are also discussed.

621.396.619.11/.13 1504

A.M. and Narrow-Band F.M. in U.H.F. Communications: Parts 1 and 2—E. Toth. (*Electronics*, vol. 22, pp. 84–91 and 102–108; February and March, 1949.) A comparison based on a long-term study undertaken at the U. S. Naval Research Laboratory, dealing with typical conditions for mobile Navy communications. Advantages of AM include: (a) better weak-signal performance, (b) relative freedom from co-channel and adjacent-channel interference, (c) lower susceptibility to multipath propagation difficulties, (d) AM occupies a narrower frequency range, especially at low carrier frequencies, (e) ease of equipment alignment, (f) tolerance of severe detuning, and (g) circuit simplicity. FM has advantages for geographically fixed communication and broadcast systems, particularly for high-fidelity reproduction of speech and music. In general, FM permits the use of a smaller transmitter and requires less power for a given carrier-output rating. Transmitter modulation is difficult for FM crystal-controlled systems.

621.396.619.11/.13 1505

Reduction by Limiters of Amplitude Modulation in an Amplitude- and Frequency-Modulated Wave—A. G. Clavier, P. F. Panter, and W. Dite. (*Elec. Commun.*, vol. 25, pp. 291–299; September, 1948.) The limiting action of ideal and imperfect limiters is analyzed mathematically by the use of the Fourier transform. Curves are given, for various applied carrier voltages, showing the reduction of AM by theoretical limiters having static characteristics represented by known mathematical functions. See also 3110 of 1944 (Bennett).

621.396.619.13:621.396.65:621.396.11 1506

The Possibility of Transatlantic Transmission by Means of Frequency Modulation—L. B. Arguimbau and J. Granlund. (*Atti del Congresso internazionale della Radio* (Rome), pp. 671–679; September and October, 1947. In English.) An analysis of the problem of multipath interference to FM telephonic communication. An experimental circuit is described in which a source using FM is fed to the receiver through two paths, one a simple attenuator and the other a $\frac{1}{2}$-ms supersonic delay line. Preliminary tests appear promising.

621.396.65:621.396.41 1507

Multiplex U.H.F. Radiotelephone Links—H. Chireix. (*Atti del Congresso internazionale della Radio* (Rome), pp. 717–745; September and October, 1947. In French.) Methods of calculating signal-to-noise ratio, fully discussed in 2902 of 1947, are summarized. For systems using simple carrier-current FM, high signal-to-noise ratio can be obtained for a large number of channels. Overmodulation effects are much less serious than for AM. The pass band is relatively narrow. These advantages are offset by high cost, which is greatly reduced if two coaxial cables equipped for carrier current are available. Double carrier-current FM is a system particularly suitable at cm λ; reflex klystrons are used whose frequency can, at present, be varied by as much as $\pm$ 7 Mc at 3,000 Mc; the disadvantage of low power output is likely to be rectified soon. Pulse-time modulation systems have the advantage of requiring simple apparatus which can be easily installed. The main disadvantages are that signal-to-noise considerations tend to limit their use to multiplex links with only a small number of channels, crosstalk may be very objectionable and the pass band required is appreciably wider than for the FM systems considered. See also 2307 of 1946.

621.396.65(45) 1508

Experimental U.S.W. Multiplex Radiotelephone Link between Milan and Rome—F. Vecchiacchi. (*Atti del Congresso internazionale della Radio* (Rome), pp. 915–927; September and October, 1947. In Italian.) The total direct distance is 475 km; two intermediate mountain relay stations are used, so that this is split up into optical paths of 160, 260, and 70 km. Frequencies are between 150 and 220 Mc, with horizontal polarization. There are 7 channels. Performance has been continuously satisfactory; crosstalk is completely absent. See also 3750 of 1946.

621.396.931 1509

Railroad Radio—W. D. Hailes. (*Elec. Eng.*, vol. 68, pp. 1–7; January, 1949.) Description of two systems and the associated equipment: (a) a narrowband FM system inductively coupled to telegraph wires near the track; frequency is between 70 and 200 kc, input power 270 watts, output 30 to 40 watts, range about 30 miles train-to-station or 15 to 20 miles between trains; (b) a 4-channel FM space radiation system; input power is 425 watts, radiated power 50 watts, bandwidth 1.2 Mc; range depends upon terrain but is usually less than for system (a). The advantages and uses of both systems are discussed.

621.396.932.029.63 1510

An Early Application of Decimetre Waves to Communication between Ships—E. C. S. Megaw and W. E. Willshaw (*Atti del Congresso internazionale della Radio* (Rome), pp. 790–828; September and October, 1947. In English.) Experimental work in the development, for the Admiralty, of equipment to provide reliable all-round communication at distances up to 3 miles. The stabilized transmitter used a 4-segment magnetron and provided frequencies of 515, 530, 635, and 650 Mc by means of plug-in resonators. Modulation was effected by af interruption of the carrier, with marking and spacing frequencies of 1,000 cps and 3,200 cps respectively. The oscillatory circuit of the superregenerative receiver consisted of a short length of parallel-strip line; this was tuned by a symmetrical capacitor, on the stator plates of which an acorn triode was mounted. The frequency range 415 to 705 Mc was covered in 8 steps, selected by changing the position of a preset capacitor bridge. The antenna, of constant impedance 70 Ω, comprised a $\lambda/4$ radiator with a $\lambda/4$ compensating reactance transformer. Details are given of equipment performance during trials in 1939 and of measurements made to determine diffraction losses produced by masts and superstructure. A much simplified model was built in 1940 to provide a single communication channel.

621.396.933 1511

Aircraft Radio Communication Set A.R.I. 5272—E. C. Fielding. (*Elec. Commun.*, vol. 25, pp. 244–255; September, 1948.) Description of an AM transmitter-receiver originally designed for naval aircraft. Any of 4 predetermined crystal-controlled spot frequencies in the range 115 to 140 Mc can be selected by a switch; channel-changing only takes 3 seconds. The transmitter output is 3.5 watts and the range is 100 miles to ground or 200 miles to another aircraft. The set can be used under extreme tropical or arctic conditions.

621.396.97(73) 1512

F.M. Broadcasting in the United States—

E. M. Ostlund and G. S. Wright. (*Atti del Congresso internazionale della Radio* (Rome), pp. 829–850; September and October, 1947. In English.) Results of tests in the broadcast band 88 to 105 Mc on FM and AM receivers show that the former have better signal-to-noise ratio and freedom from interference. FM transmitters, methods of modulation, and and transmitting antenna systems are discussed. A brief account of networks in operation in the United States includes a contour radiation pattern for a typical station. The advantages of using FM at vhf are summarized.

SUBSIDIARY APPARATUS

621.316.7.078:016 1513

List of Russian Articles on Questions of Automatic Regulation and Following Systems for the Period 1917–1947—(*Avtomatika i Telemekhanika*, vol. 9, pp. 397–411; September and October, 1948. In Russian.)

778.53 1514

Motion Picture Photography at Ten Million Frames per Second—B. O'Brien and G. Milne. (*Jour. Soc. Mot. Pic. Eng.*, vol. 52, pp. 30–40; January, 1949.) The area to be photographed is transformed by a stationary multiple-lens and slit optical system into a number of narrow rectangles placed end to end across the moving film. The negative so formed is afterwards projected back through a similar optical system to reform a set of normal images for printing. The equipment is described in detail and illustrated, and examples of records are shown.

TELEVISION AND PHOTOTELEGRAPHY

621.397.26 1515

The [British] Post Office Phototelegraph Service to Europe—A. Wilcock. (*P.O. Elec. Eng. Jour.*, vol. 41, part 4, pp. 189–192; January, 1949.) The picture to be transmitted is scanned by light which is reflected on to a photo cell whose output is used to provide a single-sideband AM transmission at 1,300 cps. Synchronization and phasing signals are also transmitted. Both transmitter and receiver are driven by phonic motor from the output of oscillators with tuning-fork control. At the receiver, the fork frequency is synchronized manually with that at the transmitter; the receiver drum is automatically started in phase with the transmitter drum. The received picture signal is demodulated in a metal bridge rectifier and converted into a light trace by a Duddell oscillograph recording on photographic paper or film.

621.397.331.2:621.397.5 1516

Electro-Optical Characteristics of Television Systems: Part 4—Correlation and Evaluation of Electro-Optical Characteristics of Imaging Systems—O. H. Schade (*RCA Rev.*, vol. 9, pp. 653–686; December, 1948.) Continuation of 540 of March.

621.397.5 1517

Recent Progress in Television—V. K. Zworykin. (*Atti del Congresso internazionale della Radio* (Rome), pp. 928–946; September and October, 1947. In English.)

621.315.212:621.397.5 1518

The London-Birmingham Television Cable: Part 1—General System and Electrical Requirements—Stanesby and Weston. (*See* 1279.)

621.397.5:621.396.81 1519

B.B.C. Television Map—(*Wireless World*, vol. 55, pp. 55, 74; February, 1949.) Field-strength contours for the Alexandra Palace 45-Mc video transmitter.

621.397.5:621.396.81 1520

Field Test of Ultra-High-Frequency Television in the Washington Area—Brown. (*See* 1480.)

621.397.5:621.396.813 1521

Delay Distortion in Television Transmission and its Measurement—S. H. Padel. (*BBC Quart.*, vol. 3, pp. 235–244; January, 1949.) Delay distortion can be estimated from the phase versus frequency characteristic or from modulation phase shift. The methods are described in detail. Block diagrams of measuring apparatus are given, and the degree of improvement made possible by delay equalizers is discussed.

621.397.5:621.396.82 1522

The Effect of Aircraft on the Reception of Transmissions in the 45-Mc/s Band—Rowden and Ross. (*See* 1486.)

621.397.5:791.45 1523

Television in the Cinema—A. G. D. West. (*Wireless World*, vol. 55, pp. 42–44; February, 1949.) A discussion of distribution methods, based on a paper read at the International Television Convention at Zürich (867 of April). A long-term proposal involves a very-high-definition system (900 to 1,200 lines) which will link up cinemas all over Britain and provide a variety of television programs. An experimental large-screen television service is also being developed with the existing 405-line definition; various programs can be relayed over 480-Mc radio links to selected London cinemas. See also 240 of February.

621.397.5(083.74) 1524

Comments on Standardisation of European Television Services—B. J. Edwards. (*Atti del Congresso internazionale della Radio* (Rome), pp. 746–751; September and October, 1947. In English.) A frame scan frequency of 50 cps, a standard interlacing index, and 405 lines per frame are advocated; detailed reasons are given. Various technical improvements are also suggested.

621.397.5(44) 1525

French Work on Television—R. Barthélemy. (*Atti del Congresso internazionale della Radio* (Rome), pp. 680–682; September and October, 1947. In French.)

621.397.62 1526

Motorola Television Receiver—Model VT. 71—(*Radio Franç.*, pp. 10–13; February, 1949.) Discussion of general characteristics and special features, together with a detailed circuit diagram.

621.397.62 1527

Superheterodyne Television Unit: Part 1—(*Wireless World*, vol. 55, pp. 61–65; February, 1949.) Circuit and construction of a long-range sound and vision receiver. Single-sideband operation and rejector circuits are used to secure adequate sound-channel rejection. It is expected that only minor modifications will be necessary for reception of the future BBC Birmingham transmissions. The unit can be used with an external audio amplifier and may replace the straight receiver described previously (1186 of 1948 and back references). To be continued.

621.397.645 1528

Stagger-Peaked Video Amplifiers—Easton. (*See* 1344.)

TRANSMISSION

621.396.61 1529

Description of a 1-kW Medium-Wave Broadcasting Transmitter—P. Paris and J. Polonsky. (*Ann. Radioélec.*, vol. 3, pp. 293–298; October, 1948.) The feedback principles previously described (3377 of 1948) are applied in a transmitter for the range 272.5 to 750 kc; it can be used with or without crystal control and can form the driving unit of a high-power transmitter. Performance curves are given.

621.396.61.029.62 1530

The "Little Slugger"—P. S. Rand. (*QST*, vol. 33, pp. 11–17, 122; February, 1949.) Constructional and operating details of a low-power crystal-controlled 10-meter transmitter using narrow-band FM. Adequate filtering prevents television interference. The unit may be used as a narrow-band FM exciter for an AM transmitter of higher power.

621.397.61.029.63 1531

Developmental Television Transmitter for 500–900 Mc/s—R. R. Law, W. B. Whalley, and R. P. Stone. (*RCA Rev.*, vol. 9, pp. 643–652; December, 1948.) The development of tubes and circuits for a wide-band transmitter giving a peak output power of 1 kw is described. For video modulation, a pair of uhf pulse triodes are used for cathode modulation of the push-pull rf amplifier. A feature of the output tubes is the tungsten-wire grid which has negligible emission because of its excellent cooling properties.

621.396.615.141.2 1532

The Turbator, a Single-Cavity Magnetron—Lüdi. (*See* 1556.)

621.396.619:621.396.5 1533

Systems of Modulation for Radio-Telephone Transmitters—R. Vaudetti. (*Atti del Congresso internazionale della Radio* (Rome), p. 519; September and October, 1947. In Italian.) Summary only. In the first system, the modulation transformer is replaced by two inductances, each with two windings, acting as autotransformers. In the second, applicable where the final stage has tubes in parallel, the tubes of the modulated stage are arranged in series with those of the modulator stage; load matching is thus improved.

VACUUM TUBES AND THERMIONICS

621.383 1534

The Physical Characteristics of Silver Sulphide Photocells—V. E. Kosenko and E. G. Miselyuk. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1369–1377; November, 1948. In Russian.)

621.383 1535

The Structure and the Peculiarities in the Operation of Silver Sulphide Photocells—I. R. Potapenko. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1356–1368; November, 1948. In Russian.)

621.383 1536

The Frequency Characteristics of Lead Sulphide Photocells—B. T. Kolomiets. (*Zh. Tekh. Fiz.*, vol. 18, pp. 1456–1457; November, 1948. In Russian.)

621.383 1537

Comparison of Lead-Sulfide Photoconductive Cells with Photoemissive Tubes—N. Anderson and S. Pakswer. (*Jour. Soc. Mot. Pic. Eng.*, vol. 52, pp. 41–48; January, 1949.) A comparison of the electrical characteristics and a discussion of the modifications required in present practice in the motion-picture industry to obtain optimum performance.

621.385 1538

Electron Tube Development and its Place in the Progress of Radio Art—I. E. Mouromtseff. (*Atti del Congresso internazionale della Radio* (Rome), pp. 544–577; September and October, 1947. In English.) A general review of the main developments during the author's lifetime, with discussion of (a) water-cooled tubes, (b) sealing, (c) high-frequency and uhf tubes, (d) the split-anode magnetron, (e) normal and reflex klystrons, (f) tubes for pulse operation, (g) multi-cavity magnetrons, (h) the resnatron, and (i) the traveling-wave tube.

621.385 1539

Use of Optical Polish in Valve Construction—A. Danzin and E. Despois. (*Ann. Radioélec.*, vol. 3, pp. 280–289; October, 1948.) The conditions which must be satisfied for an airtight joint between two surfaces are discussed, experimental work is described and applications to the construction of both demountable and ordinary tubes are illustrated.

621.385 1540

Analysis of a Simple Model of a Two-Beam Growing-Wave Tube—L. S. Nergaard. (*RCA Rev.*, vol. 9, pp. 585–601; December, 1948.) The gain and bandwidth of a mathematical model of a tube in which a growing wave is produced by the interaction of two electron beams is investigated. The model consists of two admixed beams, infinite in extent, and uniform except in the common direction of their velocities. The gain per unit length of the model is found to depend on the operating frequency, the current densities and the velocities of the two beams. With a tube having an interaction space 30 cm long, a gain of 120

db at 3,000 Mc, with a bandwidth of 860 Mc, should be practicable.

621.385:621.316.726.078 1541

The Transitrol, an Experimental Automatic-Frequency-Control Tube—J. Kurshan. (*RCA Rev.*, vol. 9, pp. 687–703; December, 1948.) The transitrol combines the function of local oscillator and reactance device into a single unit particularly suitable for the vhf band. Experiments with commercial tubes which led up to its design are discussed; its operation is analyzed. Its uses in FM receivers and as a FM transmitter are considered. See also 1235 of May.

621.385.012 1542

The Correspondence between the Static Characteristics and the Dynamic Parameters of Electrical Negative-Resistance Devices—G. Cartianu. (*Onde Élec.*, vol. 29, pp. 44–50; January, 1949.) Certain types of static characteristic can only correspond to certain dynamic parameters and hence to certain conditions of stability. Thus a device with a dynatron type of characteristic behaves as an inductance, while one with a characteristic of the arc type behaves as a capacitance. General rules are given for determining, from the features of the static characteristic, whether a particular device is of the inductance or the capacitance type.

621.385.029.63/.64 1543

Transverse Fields in Traveling-Wave Tubes—J. R. Pierce. (*Bell Sys. Tech. Jour.*, vol. 27, pp. 732–746; October, 1948.) A mathematical treatment of the problem of weak focusing fields. Traveling-wave tubes will have gain even if the rf field at the mean position of the electron stream is purely transverse. The addition of a longitudinal magnetic focusing field reduces the gain due to transverse fields and increases the electron velocity for optimum gain. See also 2284 of 1947.

621.396.615.141.2+621.385.029.63/.64 1544

On the Properties of Valves using a Constant Magnetic Field: Part 3—J. Brossart and O. Doehler. (*Ann. Radioélec.*, vol. 3, pp. 328–338; October, 1948.) A new type of tube is described, the traveling-wave tube with magnetic field. Two possible designs are considered, in each of which the cathode is a short cylinder with a gap, the anode a delay line of zigazg type surrounding the cathode, and a uniform magnetic field is applied in the direction of the axis. A high-frequency signal is applied to one end of the anode line and is picked up near the other end by a collector plate which also serves as a screen between input and output. The gain of such a tube is calculated, neglecting space-charge effects. The new tube has considerable advantages compared with the normal traveling-wave tube. The gain is much greater and electron currents of the order of 1 ampere can be used, compared with 10 to 20 milliamperes for the normal type of tube. The efficiency is also greater and there are only two systems of forced oscillations, while the normal tube has three. Parts 1 and 2, 261 of February. To be continued.

621.385.029.64:621.397.6 1545

On the Help which some Recent Ideas concerning U.H.F. Valves can give in Television—R. Warnecke and P. Guénard. (*Ann. Radioélec.*, vol. 3, pp. 259–280; October, 1948. Erratum, vol. 4, p. 92; January, 1949.) Full paper. Summary noted in 904 of April.

621.385.032.213 1546

Spectral Emissivity and Electron Emission Constants of Thoria Cathodes—T. E. Hanley. (*Jour. Appl. Phys.*, vol. 19, pp. 583–589; June, 1948.) The relation between true and brightness temperatures for cataphoretically deposited thoria cathodes is obtained and the constants of the Richardson equations are found from electron emission studies.

621.385.032.213:621.314.57 1547

Hot-Cathode Gas-Filled Rectifying Valves—R. Suart. (*Radio Franç.*, no. 1, pp. 17–20; January, 1949.) The characteristics of such tubes are discussed and two tubes with xenon filling (Types XV.550 and VX.7400) are described. These have mean rectified anode currents of 0.35 and 1.25 amperes respectively and a maximum inverse voltage of 10,000 volts.

621.385.032.216 1548

Poisoning Effects in Oxide-Cathode Valves—G. H. Metson. (*P.O. Elec. Eng. Jour.*, vol. 41, part 4, pp. 204–205; January, 1949.) Poisoning effects due to electron bombardment of the control grid of a tube occur at energies of the bombarding electrons corresponding to the heats of formation of compounds (oxide, chloride, and sulphate) contained in normal, cathode paste and apt to be evaporated from the cathode and deposited on the grids of a tube during manufacture. It is suggested that this poisoning occurs throughout the normal life of a tube and is reversible, the cathode reactivating by expulsion of gas when the supply of primary poisoning compounds on the grids is exhausted. In addition, there appears to be an allied, but irreversible, effect due to progressive failure of minute areas of the cathode to reactivate.

621.385.032.216 1549

Note on the Ionic Conductivity of Oxide-Coated Cathodes—S. Wagener. (*Proc. Phys. Soc.*, vol. 61, pp. 521–525; December 1, 1948.)

621.385.83.032.29 1550

Design of an Electron Gun, taking Account of the Space Charge of the Beam—H. Huber. (*Ann. Radioélec.*, vol. 4, pp. 26–32; January, 1949.) Relations between gun dimensions and electrical parameters are given for an electron beam with high current density and minimum dispersion. Experiments with the gun supplying the beam for a helix-type traveling-wave tube confirm the theory. The gun gives a current of 14 ma at 1,400 volts and after traversing the 28-cm length of the helix, the beam current reduction is only 3 per cent.

621.385.832 1551

Cathode-Ray Tube with Cylindrical Screen—A. Pinciroli. (*Atti del Congresso internazionale della Radio* (Rome), pp. 605–629; September and October, 1947. In Italian.) The essential parts are (a) an electron gun, (b) an arrangement of electrodes for providing a rotating electric field, (c) two trumpet-shaped electrodes between which the beam is deflected at right angles to the tube axis, (d) a cylindrical focusing lens, and (e) two deflecting electrodes to which a voltage proportional to the quantity under observation is applied. The advantages over a cathode-ray tube using normal cartesian or polar co-ordinates are: (a) extension of the axis of time, which is determined by means of two sinusoidal voltages of lower frequency than that of the quantity under observation, (b) two distinct electron beams can be used, and (c) there is no interaction between deflection electrodes and those which are used to determine the time axis.

621.396.615.14 1552

The Resnatron—G. E. Sheppard. (*Atti del Congresso internazionale della Radio* (Rome), pp. 643–654; September and October, 1947. In English.) A detailed description of the design and operating principles, with diagrams. The advantages over conventional tubes for high-power use at uhf are stressed.

621.396.615.141.2 1553

Rising-Sun Magnetrons with Large Numbers of Cavities—A. V. Hollenberg, N. Kroll, and S. Millman. (*Jour. Appl. Phys.*, vol. 19, pp. 624–635; July, 1948.) Disturbance from unwanted modes and the critical nature of anode and cathode dimensions prevented satisfactory operation with more than 26 open-end cavity-type vane resonators. Stable pie mode operation of pulsed magnetrons having up to 38 cavities was achieved for $\lambda \approx 1.25$ cm by the use of closed-end resonators. Increasing the number of resonators should enable existing magnetron techniques to be extended to millimeter wavelengths, and the rf power obtainable for $\lambda \geqq 1$ cm to be increased.

621.396.615.141.2 1554

The Cavity Magnetron—J. T. Randall. (*Atti del Congresso internazionale della Radio* (Rome), pp. 630–642; September and October, 1947. In English.) A review of the experimental development, carried out during the war, at Birmingham University; it includes design and method of construction, design of the high-frequency output circuit, and an outline of the underlying theory.

621.396.615.141.2 1555

A Magnetron Resonator System—E. C. Okress. (*Atti del Congresso internazionale della Radio* (Rome), pp. 578–600; September and October, 1948. In English.) A mathematical investigation of the normal modes of the symmetrical multi-sectional or vane-type magnetron. Graphs and equations enable the modes to be determined from anode-block dimensions. The relationship between the wavelengths for strapped and unstrapped resonator systems is investigated. Tables are given for designing reduced-scale prototypes for use on other wavelengths and voltages.

621.396.615.141.2 1556

The Turbator, a Single-Cavity Magnetron—F. Lüdi. (*Atti del Congresso internazionale della Radio* (Rome), pp. 529–543; September and October, 1947. In German.) See also 1660 of 1943.

621.396.615.141.2:[537.291+538.691 1557

Motion of an Electron in a Cavity Magnetron—M. Panetti. (*Atti del Congresso internazionale della Radio* (Rome), pp. 601–605; September and October, 1947. In Italian.) The resonance wavelengths for the different modes are first calculated by Abele's method (3823 of 1947). The electron trajectory is regarded as differing by a small amount from the cycloidal orbit due to uniform electromagnetic and electrostatic fields; equations of motion are given applicable when certain simplifying conditions are satisfied.

621.396.615.142 1558

On the Efficiency of Velocity-Modulation Valves—P. Guénard, R. Warnecke, and C. Fauve. (*Ann. Radioélec.*, vol. 3, pp. 302–327; October, 1948. Erratum, *ibid.*, vol. 4, p. 92; January, 1949.) The factors which tend to reduce efficiency are discussed. Methods of correcting imperfections of the form of the electron packets in the 2-cavity type of tube are considered; efficiency can thus be considerably improved. The 3-cavity tube appears to be the most suitable for obtaining high-power output with good efficiency. Calculation shows that an efficiency of the order of 45 per cent is to be expected for wavelengths of 10 to 20 cm.

621.396.615.142.2:[537.291+538.691 1559

Electron Optics of H.F. Valves—D. Charles. (*Ann. Radioélec.*, vol. 4, pp. 33–47; January, 1949.) A description of the electrolyte-tank method of determining electron trajectories is illustrated by results obtained for a reflex klystron. Details are also given of a simple method which makes use of a resistance grid. For systems of cylindrical symmetry, the resistances are all equal; for revolution symmetry, the resistances are graded. Results obtained are sufficiently accurate for practical design. An analytical method is described which enables corrections for space-charge effects to be applied.

621.396.822 1560

Noise in Linear Networks—Schremp. (*See* 1488.)

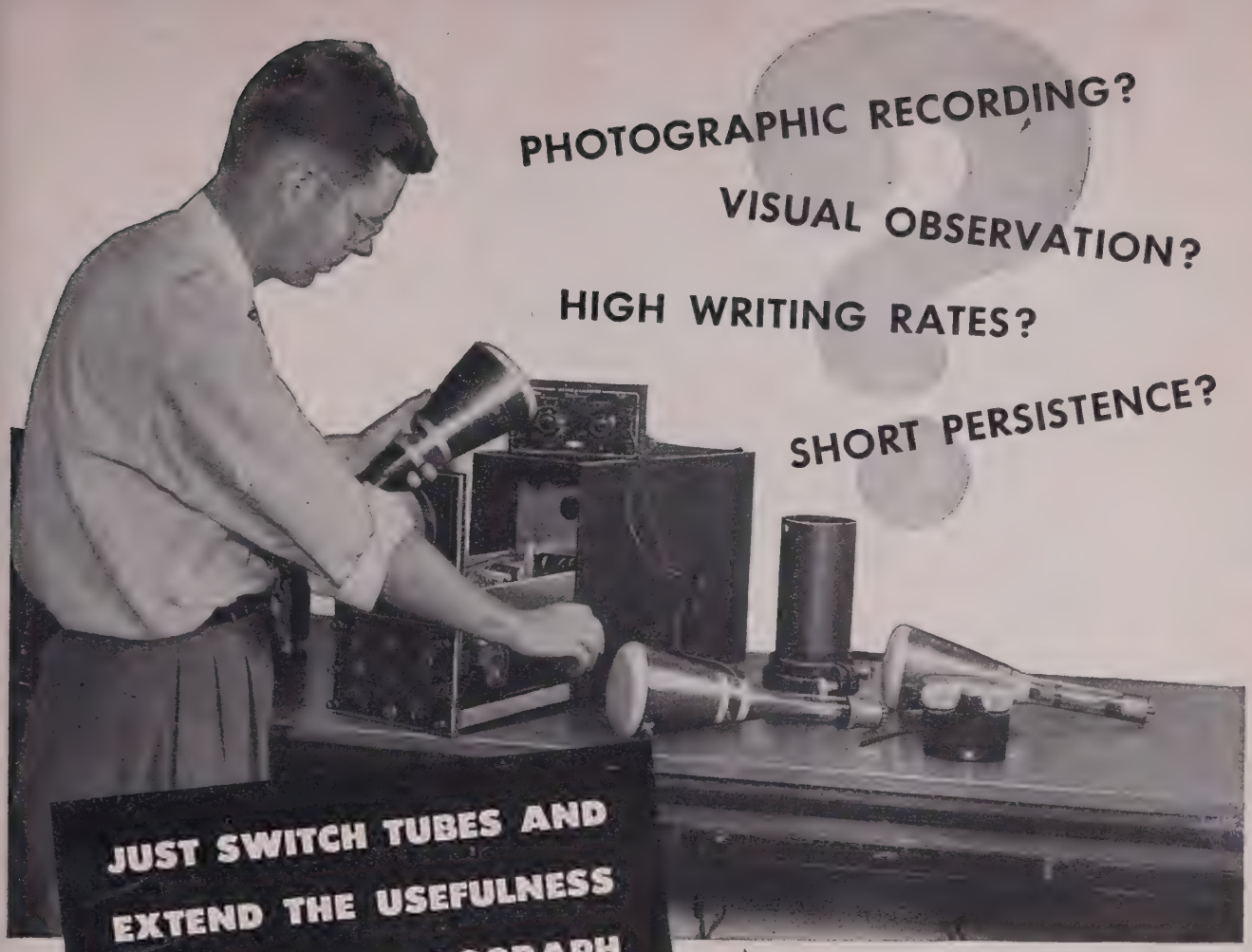
MISCELLANEOUS

022.3:621.38.001.8 1561

The Patent Office Library and Electronics—R. Neumann. (*Electronic Eng.* (London), vol. 21, pp. 52–57; February, 1949.) A general description, with special reference to electronic subjects and the indexing system.

621.396 1562

Elektrische Wellen [Book Review]—W. O. Schumann. C. Hanser Verlag, München, 340 pp. (*Wireless Eng.*, vol. 25, p. 370; November, 1948.) Based on a course of lectures at Munich University. The treatment is detailed and well illustrated.



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SECTION MEETINGS

ATLANTA

"Beam Deflection Mixer Tubes," by E. W. Herold, RCA Laboratories; October 8, 1948.

BALTIMORE

"International Telecommunications," by E. K. Jett, A. S. Abell Company; October 28, 1948.

BUFFALO-NIAGARA

"Engineering Considerations in Locating Broadcast Transmitters," by S. L. Bailey, Jansky and Bailey, Consulting Engineers; October 14, 1948.

CEDAR-RAPIDS

"Television—Its Mechanism and Promise," by W. L. Lawrence, Radio Corporation of America; October 13, 1948.

CINCINNATI

"Bandwidth Reduction in Communications Systems," by W. G. Tuller, Melpar, Inc.; September 21, 1948.

"Mobile Telephone," by R. E. Kolo, Cincinnati and Suburban Bell Telephone Company; October 19, 1948.

CLEVELAND

"Citizens Radio Equipment," by A. Gross, Citizens Radio Corporation; October 28, 1948.

COLUMBUS

"Radio in Postwar Germany," by K. L. Tyler, Ohio State University; October 27, 1948.

CONNECTICUT VALLEY

"Properties of Aluminum Oxide Film as Used in Electrolytic Capacitors; Sprague Electric Company; October 16, 1948.

DAYTON

"Aircraft Computers," by O. H. Schuck, Minneapolis-Honeywell Company; October 14, 1948.

"Stratovision," by C. E. Nobles, Westinghouse Electric Corporation; November 11, 1948.

DES MOINES-AMES

"Television—Its Mechanism and Promise," by W. L. Lawrence, Radio Corporation of America; October 15, 1948.

DETROIT

"Printed Electronic Circuits," by C. Brunetti, National Bureau of Standards; September 17, 1948.

"The Pictorial Situation Display in Air Navigation and Traffic Control," by H. H. Spencer, Radio Corporation of America; October 15, 1948.

EMPORIUM

"Engineering Considerations in Locating Broadcast Transmitters," by S. L. Bailey, Jansky and Bailey, Consulting Engineers; October 14, 1948.

INDIANAPOLIS

"Problems in Television," by B. E. Shackelford, 1948 President, The Institute of Radio Engineers; September 16, 1948.

"Television Power Supplies, Synchronizing Circuits and Deflection Systems," by C. Honeywell, The Hallicrafters Company; October 22, 1948.

LONDON

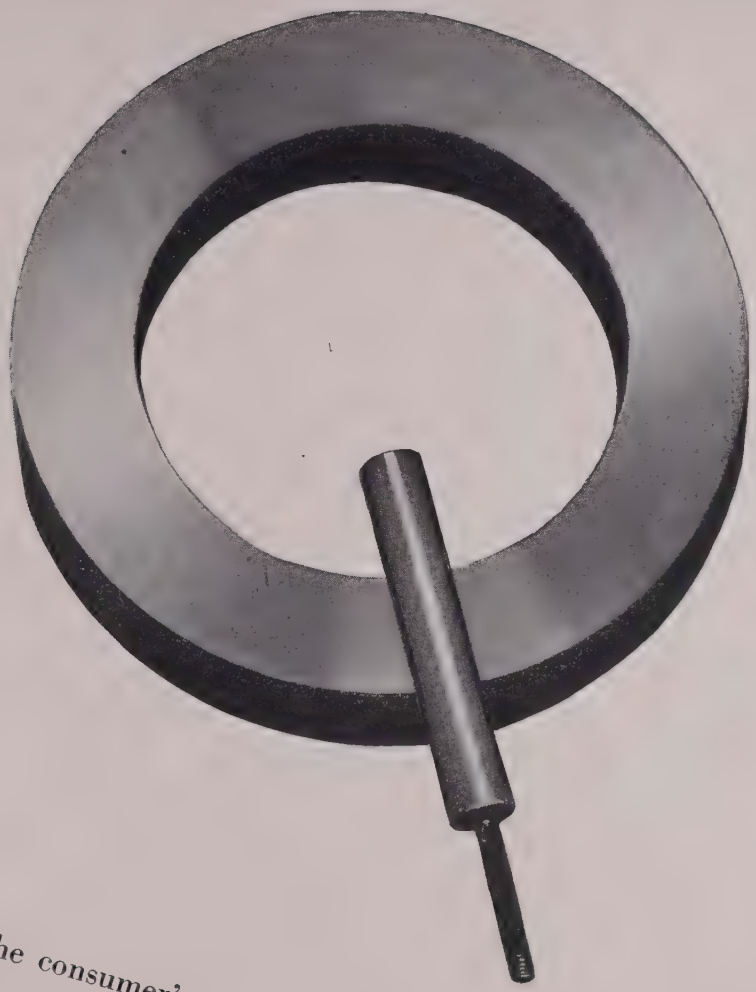
"Dry Batteries Today," by H. T. Tipple, Canadian National Carbon Company; September 24, 1948.

LOS ANGELES

"Voltage Stabilization by Two Terminal Stabilizing Elements," by D. Rutland, North American Aviation; October 19, 1948.

"Distributed Amplification," by N. B. Schrock, Hewlett-Packard Company; October 19, 1948.

(Continued on page 36A)



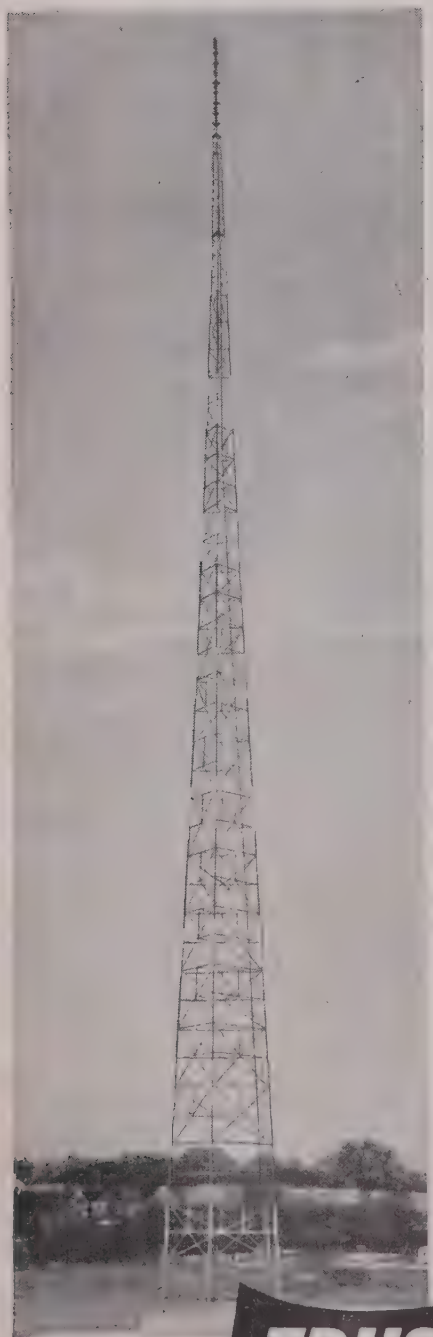
It's the consumer's fault. Last year he wanted signal quality...this year he is demanding it! That is why estimates show that practically all Television sets, *and most of the Radio sets* made in 1949 will contain cores made of Carbonyl Iron Powders. Ask your coil winder. Ask your core maker. There's a hint here for all good designers.

G. A. & F. CARBONYL IRON POWDERS

An Antara® Product of General Aniline & Film Corporation
444 Madison Avenue, New York 22, New York

WPIC

SHARON, PA.



Radio Station WPIC, Sharon, Pa., has a Truscon Type H-30 Self-Supporting Tower, 500 feet high, with 8-bay Western Electric FM

a Beauty in Appearance and Performance

Clear FM signals over hilly western Pennsylvania require an antenna with plenty of reach. That's why this Truscon Self-Supporting Steel Radio Tower climbs 500 feet with an 8-bay WE antenna for Sharon's WPIC.

An important characteristic of Truscon Radio Towers is that each is built to give top performance under specific local conditions. Truscon can engineer and manufacture exactly the tower you need—guyed or self-supporting . . . tapered or uniform cross section . . . tall or small . . . AM, FM or TV.

Write or phone our home office in Youngstown, Ohio, or any of our conveniently located district offices for prompt consultation on your present and future needs. Experienced Truscon radio engineers are ready to assist you —there is no obligation.

TRUSCON STEEL COMPANY
YOUNGSTOWN 1, OHIO
Subsidiary of Republic Steel Corporation

TRUSCON SELF-SUPPORTING AND UNIFORM CROSS SECTION GUYED TOWERS

SECTION MEETINGS

(Continued from page 34A)

LOUISVILLE

"Inspection of New Courier-Journal Building," by K. White, American Elevator Company, and J. W. May, American Air Filter Company; October 15, 1948.

NEW YORK

"Application of Microwave Radio Techniques to Telegraphy and to Sound and Video Program Transmission," by J. Z. Millar, Western Union Company; October 6, 1948.

OTTAWA

"Demonstration of the National Research Council's Radar Equipped Motor Vessel 'Radel,'" by H. R. Smythe, National Research Council; October 9, 1948.

PHILADELPHIA

"Intercarrier-Sound Circuits for Television Receivers," by A. A. Barco, RCA Laboratories; November 4, 1948.

PITTSBURGH

"The Airborne Magnetometer in Geophysical Exploration," by R. D. Wyckoff, Gulf Research and Development Company; October 11, 1948.

PORTLAND

"Design and Operation of a 5-Kw Television Transmitter," by H. W. Granberry, General Electric Company; October 29, 1948.

PRINCETON

"Electronic Properties of Semi-Conductors and the Transistor," by W. H. Brattain and J. Bardeen, Bell Telephone Laboratories; October 14, 1948.

"Electronic Reading Aids for the Blind," by V. K. Zworykin, L. E. Flory, and W. S. Pike, RCA Laboratories; November 11, 1948.

ROCHESTER

"Engineering Considerations in Locating Broadcast Transmitters," by S. L. Bailey, Jansky and Bailey, Consulting Engineers; October 14, 1948.

"A Television Station Selector Using Die-Stamped Inductances," by A. D. Sobel, A. W. Franklin Manufacturing Corporation; November 8, 1948.

"A Discussion of Image Sharpness in Photography and Television," by O. H. Schade, Radio Corporation of America; November 8, 1948.

"Application of Subminiature Tubes," by R. K. McClintock, Sylvania Electric Products, Inc.; November 8, 1948.

"The Transitrol, An Experimental AFC Tube," by J. Kurshan, RCA Laboratories; November 8, 1948.

"A New Low-Noise, Low-Microphonic Miniature Tube," by C. R. Knight and A. P. Haase, General Electric Company; November 8, 1948.

"What's When in America," by K. W. Jarvis, Consulting Engineer November 8, 1948.

"Radio Receiver Engineering Department Organization," by A. G. Rogers, Emerson Radio and Phonograph Corporation; November 9, 1948.

"Developments in Germanium Crystals," by S. T. Martin and H. Heins, Sylvania Electric Products, Inc.; November 9, 1948.

"A Television Distribution System for Laboratory Use," by J. Fisher, Philco Corporation; November 9, 1948.

"A Direct Coupled Video and ACC System for Television Receivers," by H. R. Shaw, Colonial Radio Corporation; November 9, 1948.

(Continued on page 38A)

FREQUENCY SHIFT EXCITER —Provides RF drive and frequency shift keying to transmitter

B&W DISTORTION METER MODEL 400

B&W AUDIO OSCILLATOR MODEL 200

B&W AUDIO FREQUENCY METER MODEL 300

2 KW AMPLIFIER—Class C RF Amplifier. Range: 1-25 Mc's.

THE *TRADEMARK* THAT *GREW* through service to you!

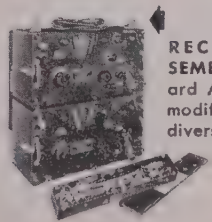
Today, the Barker and Williamson trademark is backed by three plants, excellent manufacturing facilities, and a competent technical staff—all because you have shown a definite preference for quality products and a willingness to try practical ideas that give promise of improved performance. Today, too, this famous trademark appears on many new items of complete equipment—all produced by an organization that grew because it designed and built the kind of products you wanted. With its improved facilities, B&W pledges to continue to build better and better parts and equipment, and to develop and offer only those products which you can use with confidence and pride.

CONTROL UNIT — Operates as an electronic repeater in teletype lines.

DUAL DIVERSITY CONVERTER—Provides diversity mixing on frequency shift circuits.

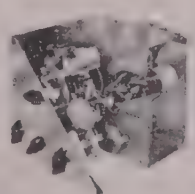
NOW IN PRODUCTION AT B&W

Complete Radio Transmitters • Dual Diversity Converters, Control Units and Frequency Shift Exciters for Radio Teletype Transmission • Special Test Equipment • Redesign, Modernization and Modification of Existing Equipment • Machine Work • Metal Stamping • Coils • Condensers • Other Electronic Devices in a Wide Range of Types.



RECEIVER ASSEMBLY — Standard Army BC-342 modified for dual diversity reception.

B&W ALL BAND FREQUENCY MULTIPLIER MODEL 504



BARKER & WILLIAMSON, INC.

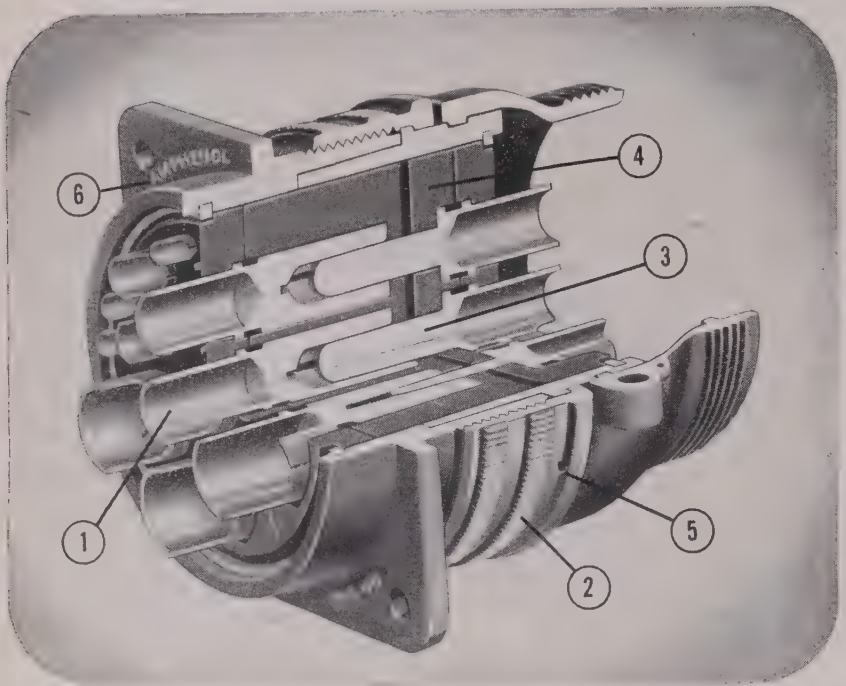
237 FAIRFIELD AVE. UPPER DARBY, PA.

B&W SINE WAVE CLIPPER MODEL 250

Specify...

AMPHENOL

"AN" CONNECTORS



FOR POWER, SIGNAL and CONTROL CIRCUITS in AIRCRAFT and ELECTRONIC EQUIPMENT

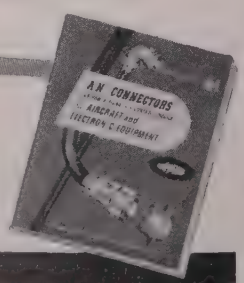
• Amphenol provides features which compare to and carry beyond the specifications for "AN" Connectors.

1. Non-rotating contacts with solder cups aligned for fast efficient soldering.
2. Coupling rings are a screw machine part made from solid aluminum bar stock providing 80% greater tensile strength.
3. Contacts are of selected high conductivity alloys, silver plated and with pockets pretinned for soldering.
4. On sizes 20 and up, Amphenol provides 70% thicker inserts—stronger to withstand rugged operating conditions.
5. Coupling rings and assembly screws are drilled for safety wiring in accordance with Army-Navy specifications.
6. For satisfaction and security be sure with "AMPHENOL."

• Let Amphenol engineers and technicians assist you in specifying connectors for application and adaptability in instrument, power and control problems — these men are available for consultation without obligation.

72 PAGES OF "AN" CONNECTORS

This is a new catalog, just off the presses a few months; long enough, however, to receive the acclaims of top engineers as the most complete and informative on the subject of "AN" Connectors. We are glad to provide a copy for your reference, kindly make request on company letterhead to our Department 13E.



AMERICAN PHENOLIC CORPORATION

1830 SO. 54TH AVENUE • CHICAGO 50, ILLINOIS

SECTION MEETINGS

(Continued from page 36A)

"A Pulse-Cross Generator for Television Receiver Production," by R. P. Burr, Hazeltine Electronics Corporation; November 9, 1948.

"Lightweight Pickup Design for Microgroove Record Playing," by R. P. Haines, Philco Corporation; November 10, 1948.

"What Constitutes High Fidelity," by H. P. Fletcher, Bell Telephone Laboratories, J. K. Hilliard Altec Lansing Corporation; and C. J. LeBel, Consultant; November 10, 1948.

"High-Quality Audio System for Radio Receivers," by R. S. Anderson and B. E. Atwood, Stromberg-Carlson Company; November 10, 1948.

"Front Ends of Television Receivers," by J. O. Silvey, General Electric Company; November 10, 1948.

"A Picture-And-Sound-Modulated Generator for Television Receiver Production," by W. R. Stone, Hazeltine Electronics Corporation; November 10, 1948.

"Industrial Applications of Photography," by W. Clark, Eastman Kodak Company; November 10, 1948.

Sacramento

"TV Equipment and Components of Systems," by R. B. Newman, Radio Corporation of America; October 19, 1948.

St. Louis

"The Baldwin Electronic Organ," by J. F. Jordan, Baldwin Piano Company; October 20, 1948.

San Francisco

"The Application of Radar Techniques to Modern Aviation," by R. J. Shank, Hughes Aircraft Company; October 13, 1948.

Seattle

"Television Station Equipment and its Functions," by H. W. Granberry, University of Washington; October 25, 1948.

Toledo

"Electronic Applications to Industrial Weighing," by D. D. Mallory, Toledo Scale Company; October 18, 1948.

Toronto

"Objectives of a University Training in Electrical Engineering," by G. F. Tracy, University of Toronto; October 25, 1948.

Twin Cities

"Computers for Aeronautical Navigation," by H. Schuck, Minneapolis-Honeywell Company; October 19, 1948.

Washington

"A Field Test of Ultra-High-Frequency Television in the Washington Area," by R. D. Kell and G. H. Brown, RCA Laboratories; October 11, 1948.

"Application of Microwave Radio Techniques to Telegraphy and to Sound and Video Program Transmission," by J. Z. Millar, Western Union Telegraph Company; November 8, 1948.

SUB-SECTIONS

Hamilton

"Current Trends in Radio Engineering," by R. A. Hackbusch, Stromberg-Carlson Company; October 18, 1948.

"Television Antennas," by H. S. Dawson, Canadian General Electric Company; November 1, 1948.

Lancaster

"Aberrations of Lenses," by R. Kingslake, Eastman Kodak Company; October 12, 1948.

Long Island

"Tape Speed as it Affects Magnetic Recording," by R. H. Ranger, Rangertone, Inc.; October 13, 1948.

MICROWAVE PLUMBING

10 CENTIMETER

"S" BAND CRYSTAL MOUNT, gold plated, with 2 type "N" connectors $12.50
POWER SPLITTER, 726 Klystron input, dual "N" ouput $5.00
MAGNETRON TO WAVEGUIDE coupler with 721-A duplexer cavity, gold plated $27.50
10 CM WAVEGUIDE SWITCHING UNIT, switches 1 input to any of 3 outputs, Standard 1½" x 3" guide with square flanges. Complete with 115 vac or d.c. arranged switching motor. Mfg. Raytheon. CRP 24AAS New and complete $150.00
10 CM. END-FIRE ARRAY POLYRODS ...$1.75 ea.
"S" BAND Mixer Assembly, with crystal mount, pick-up loop, tunable output $3.00
721-A TR CAVITY WITH TUBE, Complete with tuning plungers $12.50
10 CM. McNALLY CAVITY Type SG $3.50
WAVEGUIDE SECTION, MC 445A, rt. angle bend, 5½ ft. OA. 8" slotted section $21.00
10 CM. OSC. PICKUP LOOP, with male Homedell output $2.00
10 CM. DIPOLE WITH REFLECTOR in lucite ball, with type "N" or Sperry fitting $4.50
10 CM. FEEDBACK DIPOLE antenna, in lucite ball, for use with parabola $8.00

⅞" RIGID COAX—⅜" I.C.

RIGHT ANGLE BEND, with flexible coax output pick-up loop $8.00
SHORT RIGHT ANGLE bend, with pressurizing nipple $3.00
RIGID COAX to flex coax connector $3.50
STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $5.00
RT. ANGLES FOR ABOVE $2.50
⅞" COAX. ROTARY JOINT $8.00
RT. ANGLE BEND 15" L. OA $3.50
FLEXIBLE SECTION, 15" L. Male to female ..$4.25
MAGNETRON COUPLING to ⅞" rigid coax with TR pickup loop, gold plated $7.50

⅞" RIGID COAX—¼" I.C.

⅞" RIGID COAX, BEAD SUPPORTED per ft. $1.20
SHORT RIGHT ANGLE BEND $2.50
ROTATING JOINT, with deck mounting $6.00
RIGID COAX slotted section CU-60/AP $5.00

3 CENTIMETER PLUMBING

(STD. 1" x ½" GUIDE, UNLESS OTHERWISE SPECIFIED)

"X" BAND PREAMPLIFIER, consisting of 2-723A/B local oscillator-beacon feeding waveguide and TR/-ATR Duplexer section, including 60 mc. IF amp. $47.50
RANDOM LENGTHS of waveguide, 6 in. to 18 in. long .....$1.10/ft.
WAVEGUIDE RUN, 1½" x ½" guide, consisting of 4 ft. section with rt. angle bend on one end and 2", 45 deg. bend other end $8.00
WAVEGUIDE SECTION, 1½" x ½" choke to choke, 4 ft. long $6.75
DUMMY LOAD, TS 332/UP $22.50
"X" Band pressurizing gauge section, with 15-lbs. gauge and pressurizing nipple $18.50
45 DEG. TWIST, 6" Long $10.00
12" SECTION, 45 deg. twist, 90 deg. bend $6.00
11" STRAIGHT WAVEGUIDE section choke to cover. Special heavy construction, silver plated $4.50
15 DEG. BEND, 10" choke to cover $4.50
5 FT. SECTIONS, choke to cover $14.50
18" FLEXIBLE SECTION $17.50
"E" and "H" PLANE BEND $12.50
BULKHEAD FEED THRU $15.00
"X" BAND WAVEGUIDE, 1¼" x ⅝" OD, 1/16" wall, aluminum .....per ft. $ .75
WAVEGUIDE, 1" x ½" I.D. per ft. $1.50
TR CAVITY for 724-A TR tube $3.50
3" FLEX SECTION, square flange to circular flange adapter $7.50
724 TR tube (41-TR-1) $2.50
WAVEGUIDE SECTION, CG 251/APS-15A, 26" long choke to cover, with 180 deg. bend of 2½" rad. at one end $6.00
SWR MEAS. SECTION, 4" L, with 2 type "N" output probes mtd full wave apart. Bell size guide. Silver plated $10.00
ROTARY JOINT with slotted section and type "N" output pickup $8.50
WAVEGUIDE SECTION, 12" long choke to cover, 45 deg. twist & 2½" radius, 90 deg. bend $4.50
SLUG TUNER/ATTENUATOR, W.E. guide, gold plated $6.50
TR/ATR DUPLEXER section with iris flange ...$8.00
TWIST 90 deg., 5" choke to cover, w/press nipple $6.50
WAVEGUIDE SECTIONS 2½ ft. long, silver plated, with choke flange $5.75
WAVEGUIDE, 90 deg. bend E plane, 18" long ..$4.00
ROTARY JOINT, choke to choke $6.00
ROTARY JOINT, choke to choke, with deck mounting $6.00
S-CURVE WAVEGUIDE, 8" long cover to choke $3.50
DUPLEXER SECTION for 1B24 .....$10.00
CIRCULAR CHOKE FLANGES, solid brass .... .55
SQ. FLANGES, FLAT BRASS .....ea. .55
APS-10 TR ATR DUPLEXER section with additional iris flange $10.00
CU 105/APS 31 Directional coupler, 25 db $15.00
CU 106/APS 33 Directional coupler, 25 db $15.00
CG 176/AP Directional coupler, 20 db $18.00
FLEX. WAVEGUIDE .....$4.00/Ft.
"X" BAND calibrated attenuator $85.00
SHIELDED KLYSTRON tube mounts with rough attenuator outputs $90.00
2½" FLEXIBLE SECTION, cover to cover $5.00
SHORT ARM "T" section, with additional choke output on vertical section $4.00

1.25 CENTIMETER

"K" BAND FEEDBACK-TO-PARABOLA HORN, with pressurized window $30.00
MITRED ELBOW cover to cover $4.00
TR/ATR SECTION choke ot cover $4.00
FLEXIBLE SECTION 1" choke to choke $5.00
KBAND Rotary Joint $45.00
ADAPTER, rd. cover to sq. cover $5.00
MITRED ELBOW and S sections choke to cover $4.50
DEHYDRATING UNIT, 60 lb. capacity, 115 v. 60 cy operation, 2' x 22" x 15", New and complete $425

VARISTORS W.E.

D-171631	...$.95	D-168549	...$.95
D-167176	...$.95	D-162482	...$3.00
D-168687	...$.95	D-99136	...$1.65
D-171812	...$.95	D-166271	..$2.50
D-171528	...$.95	D-162356	..$1.50
D-163298	...$.95	D-161871A	$2.85

THERMISTORS—W.E.

D-167332 (tube) .....$.95
D-170396 (bead) .....$.95
D-167613 (button) .....$.95
D-166228 (button) .....$.95
D-164699 FOR MTG. in "X" Band Guide $2.50
D-167018 (tube) .....$.95

COAX CONNECTORS

831SP	.....$.35	UG 254/U	..$.75
831AP	.....$.35	UG 255/U	.$1.25
831HP	....$.15	UG 146/U	.$1.00
UG 21/U	...$.85	UG 85/U	..$1.25
UG 86 U	...$.95		

Homedell male to type "N" male adapter $1.25
D-166366 Baby "N" .....$ .85
Adapatre Cable Ass'y, Type "N" Male to Type "N" Female $2.25
Adapter Cable Ass'y, Sperry Male to Type "N" Male $2.25
Connector, #49579 for RG 18/U $1.80

DYNAMOTORS

Type	Input Volts	Input Amps	Output Volts	Output Amps	Radio Set	Price
BD 7/KM	14	40	1000	.350	BC 191	$20.00N
						14.00LN
PE 73	28	19	1000	.350	BC 375	24.50N
DM 21CX	28	1.6	235	.090	BC 312	3.45N
DM 25	12	2.3	250	.050	BC 367	2.49LN
DM 28R	28	1.25	275	.070	BC 348	8.75N
DM 33	28	7	540	.250	BC 456	5.50
DM 42	14	46	1030	.050		
			2/8			
CWD 21AAX	13	12.6	400	.135		17.50N
	26	6.3	800	.020		
			9AC	.112		
D 104	12		225	.100		14.95N
			440	.200		
DA 3A*	28	10	300	.260	SCR 522	8.95N
			150	.010		
			14.5	5		
#5053	28	1.4	250	.060	APN 1	3.95N
DA 7A	26.5		1100	.400	TA 2J	25.00N
PE 86	28	1.25	250	.060	BC 36	3.95
23350	27	1.75	285	.075	APN-1	3.50N
35X045B	28	1.2	250	.060		3.50N
ZA .0515	12/24	1/2	500	.050		3.95N
B-19 PACK	12	9.4	275	.110	Mark II	
			500	.050		9.95N

N—New. LN—Like new.
*—Less, Filter Box and Relays

INVERTER PE 218

Input: 27.5 V DC, 90 AMPS
Output: 115 V AC, 400 CY, 13 AMPS
1500 Volt—Amperes
.9 PF
New, Original Packing $49.95
Slightly used, ex. cond. 25.00
Also available: PE 206, 800CY, 80V. New $15.75

MAGNETRONS

TUBE	FRQ. RANGE	PK. PWR. OUT.	PRICE
2J31	2820-2860 mc.	265 KW.	$25.00
2J21-A	9345-9405 mc.	50 KW.	25.00
2J22	3267-3333 mc.	265 KW.	25.00
2J26	2992-3019 mc.	275 KW.	25.00
2J27	2965-2992 mc.	275 KW.	25.00
2J32	2780-2820 mc.	285 KW.	25.00
2J38 Pkg.	3249-3263 mc.	5 KW.	25.00
2J39 Pkg.	3267-3333 mc.	87 KW.	25.00
2J55 Pkg.	9345-9405 mc.	50 KW.	25.00
2J61	3000-3100 mc.	35 KW.	65.00
2J62	2914-3010 mc.	35 KW.	65.00
3J31	24,000 mc.	50 KW.	55.00
5J30			39.50
714AY			25.00
720BY	2800 mc.	1000 KW.	50.00
720CY			50.00
725-A	9345 9405 mc.	50 KW.	25.00
730-A	9345-9405 mc.	50 KW.	25.00
Klystrons:	723A/B $12.50; 707B W/Cavity		20.00

MAGNETRONS MAGNETS

GAUSS	POLE DIAM.	SPACING	PRICE
4850	¾ in.	⅝ in.	$12.50
2500	1⅝ in.	1 11/16 in.	12.50
1500	1⅝ in.	1½ in.	12.50

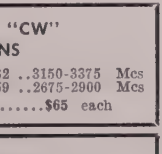
TUNABLE PKG'D "CW" MAGNETRONS

QK61 ..2975-3200 Mcs QK62 ..3150-3375 Mcs
QK60 ..2800-3026 Mcs QK59 ..2675-2900 Mcs
New .....$65 each

COAX CABLE

RG 17/U. 52 ohm imp. .....$.50/ft.
RG 18/U. 52 ohm imp. armored ..... .51/ft.
RG 23/U. twin coax, 125 ohm imp. armored .50/ft.
RG 28/U. 50 ohm imp. pulse cable. Corona min. starting voltage 17 KV. ..... .50/ft.
RG 35/U. 70 ohm imp. armored ..... .50/ft.
RG 57/U. 95 ohm imp. twin coax, ... .35/ft.

MICROWAVE TEST EQUIPMENT



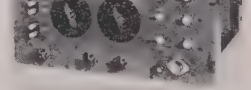
THERMISTOR BRIDGE: Power meter I-203-A. 10 cm. mfg W.E. Complete with meter, interpolation chart, portable carrying case $72.50
Bell Labs. Dual Mount mixer-beacon assemblies. 2 complete mixer-beacon mounts on gold-plated waveguide section $50.00
Slotted Line, Bell Labs, 1½" x 5/16" guide, gold plated $150.00
TS-238-GP. 10 cm. Echo box with resonance indicator and micrometer adjust cavity. 2700 to 2900 Mcs calibrated as shown $85.00
TS 108-AP dummy load $65.00
3 cm. Wavemeter, Micrometer head mounted on X-Band guide. Freq. range approx. 7900 to 10,000 Mc. $75.00

MICROWAVE GENERATORS

AN/APS-15A "X" Band compl RF head and modulator, incl. 725-A magnetron and magnet, two 723A/B klystrons (local osc & beacon), 1B24 TR, revr-ampl, duplexer, HV supply, blower, pulse xfmr. Peak Pwr Out: 45 KW apx. Input: 115, 400 cy. Modulator pulse duration .5 to 2 micro-sec apx. 13 KV Pk Pulse. Compl with all tubes incl. 715-B, 829B, RKR 73, two 72's Compl. pkg, new $210.00
APS-15B. Complete pkg. as above, less modulator $150.00

PULSE EQUIPMENT

MODULATOR UNIT BC 1203-B



Provides 200-4,000 PPS. Sweep time: 100 to 2,500 microsec. in 4 steps. fixed mod. pulse, suppression pulse, sliding modulating pulse, blanking voltage, marker pulse, sweep voltages, calibration voltages, fil. voltages. Operates 115 vac, 50-60 cy. Provides various types of voltage pulse outputs for the modulation of a signal generator such as General Radio #804B or #804C used in depot bench testing of SCR 695, SCR 595, and SCR 535. New as shown $125.00
MIT. MOD. 3 HARD TUBE PULSER Output Pulse Power: 114 KW (12 KV at 12 amp). Duty Ratio: .001 max. Pulse duration: .5, 1.0, 2.0 microsec. Input voltage: 115 v. 400 to 2400 cps. Uses 1-715-B, 1-829-B, 3-72's, 1-'73. New $110.00
APQ-13 PULSE MODULATOR. Pulse Width .5 to 1.1 Micro Sec. Rep. rate 624 to 1348 Pps. Pk. Pwr. out 35 KW. Energy 0.018 Joules ...$49.00
TPS-3 PULSE MODULATOR. Pk. power 50 amp. 24 KV (1200 KW pk); pulse rate 200 PPS, 1.5 microsec; pulse line impedance 50 ohms. Circuit—series charging version of DC Resonance type. Uses two 705-A's as rectifiers. 115 v. 400 cycle input. New with all tubes $49.50
APS-10 MODULATOR DECK, Complete, less tubes $75.00
APS-10 Low voltage power supply, less tubes $18.50

PULSE NETWORKS

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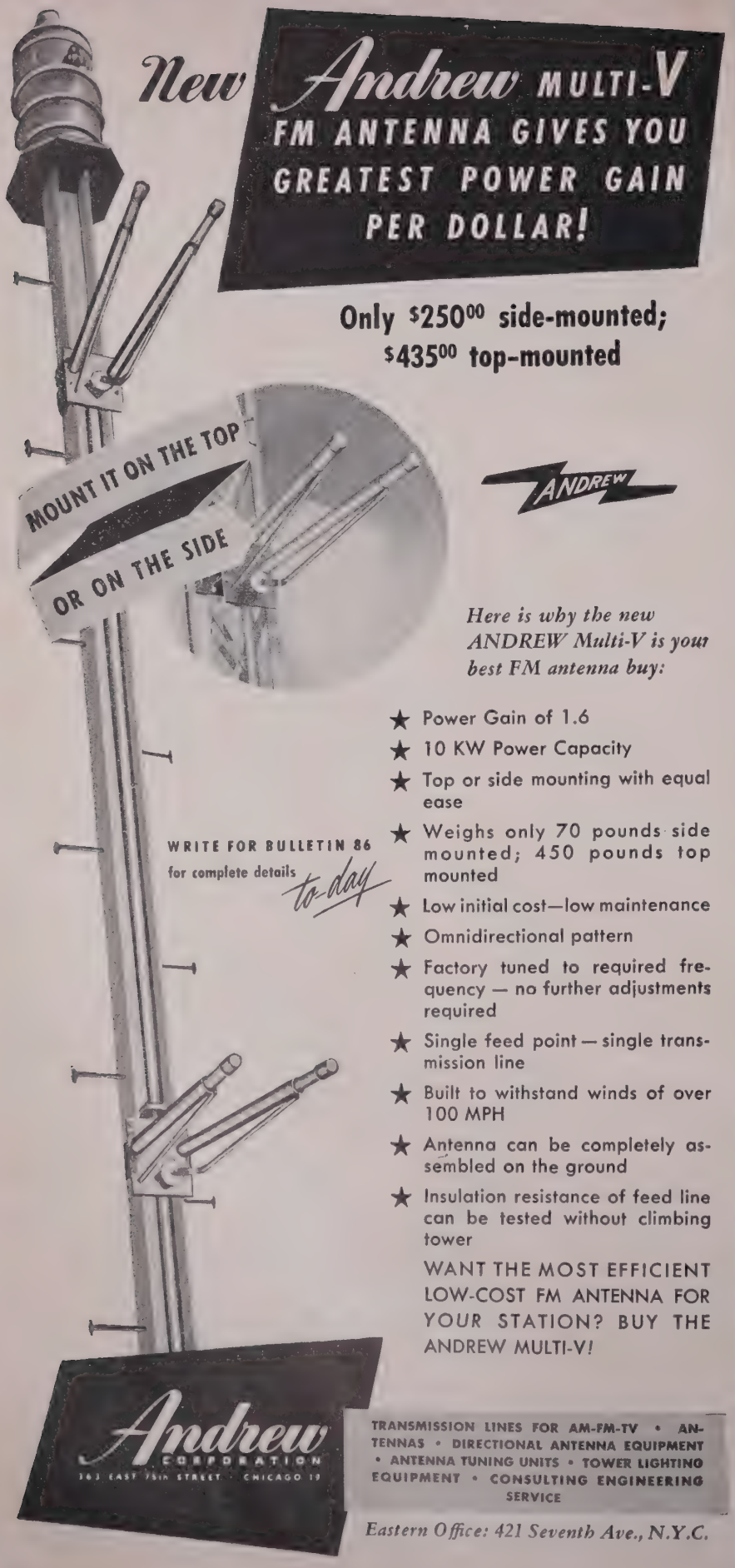
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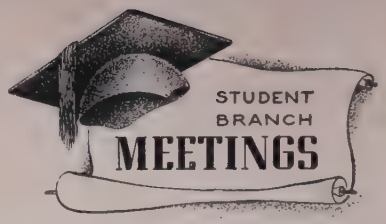

ALABAMA POLYTECHNIC INSTITUTE, IRE BRANCH

Election of Officers; October 11, 1948.

UNIVERSITY OF ARIZONA, IRE-AIEE BRANCH

"Large Business versus Small Business for the Graduate Engineer," by S. Becker, University of Arizona; October 27, 1948.

CALIFORNIA STATE POLYTECHNIC COLLEGE, IRE BRANCH

"The Relationship of the Engineering Society to the Student," by B. E. Shackelford, 1948 President, The Institute of Radio Engineers; September 29, 1948.

IOWA STATE COLLEGE, IRE-AIEE BRANCH

"Television," by T. A. Hunter, Regional Director IRE; October 19, 1948.

STATE UNIVERSITY OF IOWA, IRE BRANCH

General Electric Company Demonstration; October 19, 1948.

MANHATTAN COLLEGE, IRE BRANCH

"Insulation Testing," by W. G. Long, J. G. Biddle Company; October 20, 1948.

UNIVERSITY OF MICHIGAN, IRE-AIEE BRANCH

"Electrical Engineering Applications in Geophysical Prospecting," by J. T. Wilson, University of Michigan; October 6, 1948.

"The Transistor," by R. R. Barnes, Michigan Bell Telephone Company; October 27, 1948.

MICHIGAN STATE COLLEGE, IRE-AIEE BRANCH

"What the Professional Engineering Organizations Can Do For You," by A. Rauth, Consumers Power Testing Laboratories; October 13, 1948.

COLLEGE CITY OF NEW YORK, IRE BRANCH

"Design of a High-Fidelity Audio System," by L. M. Glantz, Student; October 19, 1948.

"High-Fidelity Systems," by L. Feldman, Student; October 19, 1948.

UNIVERSITY OF NORTH DAKOTA, IRE-AIEE BRANCH

"The Freeman Headbolt Heater," by E. Zobel Five-Star Manufacturing Company; October 13, 1948.

UNIVERSITY OF NOTRE DAME, AIEE-IRE BRANCH

"The South Bend AIEE and its Activities," by R. Koontz, Consulting Engineer; October 13, 1948.

OREGON STATE COLLEGE, IRE-AIEE BRANCH

"IRE-AIEE Societies History and Background," by F. O. McMillan, Oregon State College; September 29, 1948.

"Student Summer Jobs," by E. P. Single, J. F. Richardson, P. Foley, M. M. Matthews, J. Lynch, D. G. Wohlgemuth, D. Poley, H. Lowry, and N. Austin, Students; October 14, 1948.

RUTGERS UNIVERSITY, IRE-AIEE BRANCH

"Placement of Engineers," by J. L. Price, Rutgers University; October 26, 1948.

(Continued on page 41A)

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STUDENT BRANCH MEETINGS

(Continued from page 40A)

ST. LOUIS UNIVERSITY, IRE BRANCH

"Commercial Radio Licenses," by W. Fisher, Student; October 7, 1948.

"Mathematical Short Cuts," by O. Haly, Student; October 7, 1948.

"Operation of Station WEW-FM," J. Goforth, Student; October 14, 1948.

"Microwaves in your Telephone," by M. Waggoner, Southwestern Bell Telephone Company; October 21, 1948.

UNIVERSITY OF TENNESSEE, IRE-AIEE BRANCH

"Electrical Engineering and Atomic Energy," by D. W. Cardwell, University of Tennessee; October 26, 1948.

UNIVERSITY OF WYOMING, IRE BRANCH

"Radio-Frequency Induction Heating," by C. Kane, Student; October 7, 1948.

MEMBERSHIP

The following transfers and admissions were approved to be effective as of January 1, 1949:

Transfer to Member Grade

Berry, F. M., 1200 E. 49 St. Terr., Kansas City, Mo.
Birkenhead, W. D., 910 Second St., Manhattan Beach, Calif.
Campbell, C. A., 44 Central St., W. Concord, Mass.
Chernosky, E. J., 6608 Hillandale Rd., Chevy Chase 15, Md.
Crandon, L. H., Electronics Department, Westinghouse Research Laboratories, East Pittsburgh, Pa.
Davis, R., 2460 Silverlake Blvd., Los Angeles 26, Calif.
Davis, S., 351-99 St., Brooklyn 9, N. Y.
Dobbs, C. I., 5701 S. Hoyne Ave., Chicago 36, Ill.
Frenette, C., 54 Bougainville Ave., Quebec City, Que., Canada
Morse, M. S., Box 322, Red Bank, N. J.
Murphy, J. L., 1456 E. 54 St., Chicago 15, Ill.
Nelson, D. E., 411 W. Illinois St., Urbana, Ill.
Qureshi, M. A. A., P.O. Husain Agahi, Multan City, W. Punjab, Pakistan
Saigeon, N. D., 26783 Outer Dr., Escorse 18, Mich.
Tomiyasu, K., 2 Gray Gardens East, Cambridge 38, Mass.

Admission to Member Grade

Betts, A. L., 220 S. Husband, Stillwater, Okla.
Corwin, N. J., 2040 Baker Ave., Schenectady 8, N. Y.
Dinnick, G. M., c/o Andrew Corp., 363 E. 75 St., Chicago 19, Ill.
Eddy, R. C., 510 N. Hanover St., Elizabethtown, Pa.
Gilmer, P., 27 Beechwood Rd., Florham Park, N. J.
Greaves, H. A., Mackenzie, Rio Demerara, British Guiana, S. A.
McClain, E. F., Jr., Naval Research Laboratory, Building 1, PH, Washington 20, D. C.

(Continued on page 42A)

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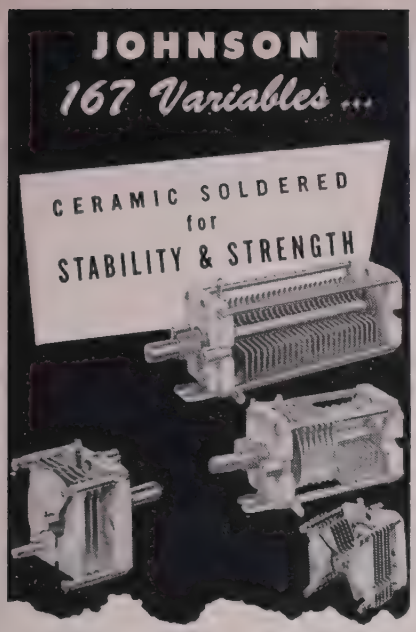
Smoll, A. E., 2511 S. State, Syracuse 5, N. Y.
Spicer, W. T., 1929 E. 31 St., Baltimore 18, M.d
Stewart, R. M., Jr., Physics Department, Iowa State College, Ames, Iowa
Tapy, R. W., University of New Mexico, Albuquerque, N. Mex.
Urquhart, K. J., Sandia Base Branch, Albuquerque, N. Mex.
Wase, A. E. N., 62 Holdenhurst Ave., London N.12, England
Zielesch, B. E., 461 Oak, Wisconsin Rapids, Wis.

The following admissions to Associate grade have been approved and were effective as of December 1, 1948:

Adler, R. L., 602 W. 165 St., New York 32, N. Y.
Aggarwol, N. H., c/o L. Banarsi Das, Advocate Hoshiar Par, East Punjab, India
Allred, C. Mc., National Bureau of Standards, Washington, D. C.
Appuhamy, F. A., "San Jose," Dankotvwa, Ceylon
Ardelian, T. E., Hudson's Bay Co., Fur Trade Department (Radio), Hudson's Bay House, Winnipeg, Manitoba, Canada
Argall, J. R. C., 104-53 Ave., Lachine, Montreal 32, Ont., Canada
Barnett, H. A., Jr., Radio Station WIST, Charlotte 2, N. C.
Berry, R. F., 17945 Harwood Ave., Homewood, Ill.
Beyer, A. R., 2019 Dunstan, Houston 5, Tex.
Blais, R. L., 282 Pleasant St., Berlin, N. H.
Buchsbaum, W. H., 80-21-74 Ave., Glendale, L. I., N. Y.
Caffrey, G. H., 103 N. Chester Ave., Hatboro, Pa.
Cancro, C. A., Naval Ordnance Laboratory, Bldg., 201, White Oak, Silver Spring, Md.
Chaney, A. L., Jr., 612 Grandin Rd., Charlotte, N. C.
Christopher, O., Box 68, Air Base Branch, Belleville, Ill.
Cooper, L. V., 1930 AACS APO 731, c/o PM Seattle, Wash.
Couch, P. W., 22 Hopeland St., Dayton, Ohio
Croumlich, R. M., Box 171, New Baden, Ill.
DeDominicis, C. M., 34 Via Filippino Lippi, Milano, Italy
Dickinson, I. E., McClatchy Broadcasting Co., 7 & Eye Sts., Sacramento, Calif.
Earley, J. M., 2120 Douglass Ave., Maplewood 17, Mo.
Edmanson, J. W. E., 2436 Shakespeare Rd., Houston 5, Tex.
Elam, F. E., 1345 Madison St., N. W., Washington 11, D. C.
Endres, J. M., Jr., 29 Fulmer Ave., Llanerch, Havertown, Pa.
Erickson, E. A., 4625 Second Blvd., Detroit 1, Mich.
Farley, B. G., Bell Telephone Laboratories, Murray Hill, N. J.
Foakes, P. F. J., 16 Bouverie Rd., Chelnisford, Essex, England
Foley, T. U., 109 E. Evesham Ave., Magnolia, N. J.
Freeman, G. A., Jr., 2117 Ave. L., Galveston, Tex.
Galbraith, A. H., 43 Crestmont Rd., Bangor, Me.
Gerstein, B., 928 George St., Chicago 14, Ill.
Gibbs, L. L., 349 Orchard Dr., Dayton 9, Ohio
Graham, J. M., Rm. 309 CAP, General Electric Company, Schenectady, N. Y.
Grdseloff, L., c/o Green's Commercial Agencies, P.O.B. 600, Cairo, Egypt
Gregersen, K. J., 4408 Greenwich Village Ave., Dayton 6, Ohio
Greulich, H. J., Box 228, APO 925, c/o Postmaster, San Francisco, Calif.
Gulczynski, R. J., 2004 W. Cullerton St., Chicago 8, Ill.
Guttwein, G. K., 24 Liberty St., Long Branch, N. J.
Heppel, H. H., Jr., 2202 S. Boulevard, Houston 6, Tex.



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Innes, F. T., 1919 Arch St., Philadelphia 3, Pa.
Isaacs, S. J., 2043 Holland Ave., New York 60, N. Y.
Jones, G. E., Jr., University of Pittsburgh, Pittsburgh 13, Pa.
Jones, O. L., 3006 Nichols Ave., S. E., Washington 20, D. C.
Jose, R. S., Hdqs. 1804, AACS Group, APO 942, c/o Postmaster Seattle, Wash.
Keep, H. A., 1110 Winbern St., Houston 4, Tex.
Kelley, N. J., 123 Ontario St., Toledo 2, Ohio
Kiley, W. A., 1235 Avant Ave., San Antonio, 3 Tex.
Koenig, J. G., 129 Hornaday Rd., Pittsburgh, 10 Pa.
Kothe, E. W., 68 Prince St., Hastings-on-Hudson 6, N. Y.
Kovner, H., 400 E. 57 St., New York 22, N. Y.
Lojkasek, T., 1961 Bartolome Mitre, Buenos Aires, Argentina
Lorenz, L. H., 1250 Wakefield Dr., Houston 18, Tex.
Lundahl, S. E., 190 Nagle Ave., New York 34, N. Y.
Mack, S. J., 81 Brook St., Wollaston 70, Mass.
Mahaffey, R. E., 615 S. Darling, Angola, Ind.
Manson, W. R., 4016 44 Ave. S., Minneapolis, Minn.
Margulius, M. P., Acoyte 143-VII H, Buenos Aires, Argentina
McCarrell, S. G., 8925 Bishop St., Chicago, Ill.
McCormick, C. E., Box 1138, Grand Junction, Col.
McDonald, H. D., 10 E. 138 St., New York 35, N. Y.
McNamara, T. R., 254-31-84 Rd., Floral Park, L.I., N. Y.
Mehta, P. E., 13 Jal Chamber, Charni Road Junction, Bombay 4, India
Myers, V. V., Jr., 413 South Broadway, Albuquerque, N. Mex.
Narula, V. P., c/o G. R. Narula Esqr., Near Water Tank A, Patiala, India
New, H. J., Jr., 3504 Harrison, Amarillo, Tex.
Pacher, F. A., 1227 39 Ave., San Francisco 22, Calif.
Padilla, D. J., R-217 D, 13 St., Sandia Base, Albuquerque, N. Mex.
Parks, R. J., 10000 La Tuna Canyon Rd., Roscoe 2, Calif.
Perelman, I. B., 28 Windermere Dr., Bronxville Hgts., Yonkers, N. Y.
Perlman, A., 160 Beach 82 St., Rockaway Beach, L.I., N. Y.
Pickens, R. T., 58 W. 75 St., New York 23, N. Y.
Platt, S., 8 Stuyvesant Oval, New York 9, N. Y.
Rabinowitz, M. H., 324 E. 81 St., New York 28, N. Y.
Rahner, H. B., Georgia Institute of Technology, Box 5388, Atlanta, Ga.
Redfield, A. H., Jr., 621 Quintana Pl., N.W., Washington 11, D. C.
Reedy, J. F., 4652 Kenmore Ave., Chicago, Ill.
Roberts, J. T., Barnard Hall, North Brother Island, New York 54, N. Y.
Root, J. S., 621 Craig St. W., Montreal 3, Ont., Canada
Rosner, M., 306 E. 75 St., New York 21, N. Y.
Rothman, L., 1820-81 St., Brooklyn 14, N. Y.
Rynder, L. S., 2372 Franklin Ave., Toledo 10, Ohio
Scovill, J. M., 20 W. Garfield St., Seattle 99, Wash.
Simon, J. M., 1511 20 St., N.W., Washington, D. C.
Smith, E. A., 2235 Kensington Rd., Dayton 6, Ohio
Stauffer, C. R., 1553 N. Wells St., Chicago 10, Ill.
Sterne, H. J., 7071 N. Wilbur St., Portland 3, Ore.
Swain, J. E., Jr., 5058½ N. Wolcott, Chicago 40, Ill.
Tompson, R. N., Mathematics Department, University of Nevada, Reno, Nev.

(Continued on page 44A)

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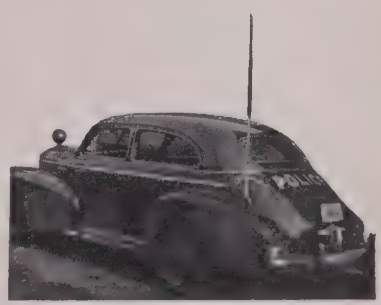

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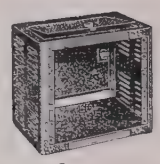

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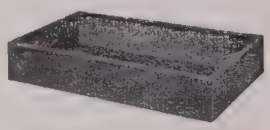
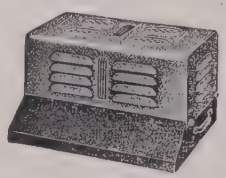


BUD Steel Chassis Bases



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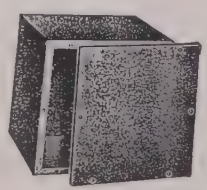

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Ulander, C. G., 1209 Shepherd St., N.W., Washington, D. C.
Wagenseller, J. E., 1017 North Ave., Secane, Pa.
Wallace, R. M., 2921 Cherrywood Ave., Dallas 9, Tex.
Whitehurst, C. H., Jr., 201 N. Highland Ave., Winter Garden, Fla.
Wilson, J. O., Box 193, Espanola, N. Mex.
Wofford, W. D., 1502 Elmen, Houston 19, Tex.
Wolfe, R. E., 9306 Harford Rd., Baltimore 14, Md.
Wynn, W. W., R.F.D. 2, Maple, Ont., Canada

The following transfers to Associate grade were approved to be effective as of December 1, 1948:

Baird, G. A., Conestoga Rd., Ithan, Pa.
Bardi, G. B., 114 West 13 St., New York 11, N. Y.
Bein, W., 610 Riverside Dr., New York 31, N. Y.
Bend, C. M., Jr., 107 Farrington St., St. Paul 2, Minn.
Billingsley, F. C., 1926 Fifth Ave., Troy, N. Y.
Boehm, W. R., 1044-26 St., S., Arlington, Va.
Borgese, A. J., 115 Harding Ave., White Plains, N. Y.
Britton, C. C., 722 Grand Ave., Ames, Iowa.
Burnett, J. R., School of Electrical Engineering, Purdue University, Lafayette, Ind.
Chambers, G. R., 194S Holliston Ave., Pasadena, Calif.
Chatterjee, A. K., 503 E. Greer St., Champaign, Ill.
Chin, F. K., 251 Victoria Ave., Hampton, Va.
Christmas, W. I., 63 Columbia Ave., Westmount, Montreal 6, Que., Canada
Clark, C. M., 3206 Nevin Ave., Richmond, Calif.
Cohen, E., 71–31 Manse St., Forest Hills, L.I., N. Y.
Culling, E. J., 107 Tenth St., N.E., Washington 2, D. C.
D'Amato, R. J., 989 New York Ave., Brooklyn 3, N. Y.
Davis, J. H., 560 E. St. John, San Jose 12, Calif.
Eisenberg, I., 1412 Vyse Ave., New York 59, N. Y.
Ellis, T. E., Jr., R.F.D. 5, Kenton, Ohio
Evenson, R. K., 463 West St., New York 14, N. Y.
Fenaughty, A. L., 2039 Stanford Ave., St. Paul X5, Minn.
Flackbert, W. D., 90 Broad St., New York 4, N. Y.
Freinmuth, W. L., 4107 Warner St., Kensington, Md.
Fusfeld, M., 710 West 173 St., New York 32, N. Y.
Gaines, W. M., 462 Third St., Schenectady, N. Y.
Godbey, J. K., 3120 Dutton Dr., Dallas 11, Tex.
Green, P. E., Jr., 226 Broad St., Oxford, N. C.
Gutsheon, W. Y., 309 W. 57 St., New York, N. Y.
Hodgin, D. M., Jr., 3206 Vine Ave., S.E., Cedar Rapids, Iowa
Huebscher, H., 1745 Eastburn Ave., New York 57, N. Y.
Hufford G., 3814 Jocelyn St., N.W., Washington 15, D. C.
Hull, D. E., 1792 37 St., Los Alamos, N. Mex.
Jacobi, W. J., Department of Electrical Engineering, Princeton University, Princeton, N. J.
Jakubowski, M. C., c/o Fairchild Aerial Surveys, Inc., 224 East 11 St., Los Angeles 15, Calif.
Jennings, S. J., 967 Main Ave., Schenectady 3, N. Y.
Joerger, J. C., 729 W. Roscoe St., Chicago 13, Ill.
Jones, P. D., Station 0–40, Sperry Gyroscope Company, Great Neck, L.I., N. Y.
Jones, W. N., Box 323, Swarthmore, Pa.
Kilby, J. S., 4924 West Lloyd St., Milwaukee 8, Wis.
Laurent, J. A., Jr., 2000 Grand Blvd., Schenectady, N. Y.
Lotz, W. E., Jr., Signal Corps, Fort Monmouth, Red Bank, N. J.

(Continued on page 45A)

MEMBERSHIP

(Continued from page 44A)

Myerhoff, A. A., 236 First St., Perth Amboy, N. J.
Minor, C. M., 5728 Blackstone Ave., Chicago 37, Ill.
Moon, R. F., U. S. Navy Electronics Laboratory, San Diego 52, Calif.
Nakahara, T., 1031 King St., Seattle 4, Wash.
Pickens, D. H., 8215 S. Vernon, Chicago, Ill.
Press, M., 137-77 - 70 Ave., Kew Garden Hills, L.I., N. Y.
Price, T. P., PUD 2, Raymond, Wash.
Quintin, W. P., Jr., 120 Lincoln Ave., Edgewood, Pa.
Richardson, L. D., 38 Hillcrest Rd., Reading, Mass.
Richter, F. A., 1031 E. 48 St., Chicago 15, Ill.
Rosar, M. T., 50 Moore Rd., Bronxville 8, N. Y.
Sample, G. A., 1123 Bellevue Ave., Syracuse, N. Y.
Santa, M. M., 805 W. 19 St., Wilmington, Del.
Saron, R. B., 345 E. 81 St., New York, N. Y.
Schrieber, W F., 48 Logan St., Brooklyn 8, N. Y.
Schwartz, E. I., 1878 Harrison Ave., New York 63, N. Y.
Sinclair, R. O., Jr., Bell Telephone Laboratories, Whippany, N. J.
Spear, E. D., 316 B. South Columbia, Albuquerque, N. Mex.
Steele, H., 227 Hopkins St., Brooklyn 6, N. Y.
Stouffer, R. L., 630 N. Cedar, Galesburg, Ill.
Tobler, C. R., 20 Sutton Pl., Verona, N. J.
Viales, L. O., 252 16 Ave., San Francisco 18, Calif.
Vincent, R. C., O.R.L., Box 30, State College, Pa.
Weaver, P. F., Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.
Weinstein, D., 2726 Valentine Ave., New York 58, N. Y.
Weissman, S., 307 Throop Ave., Brooklyn 6, N. Y.
Williams, A. M., 817 Belleview St., Amarillo, Tex.
Wilmot, R. D., 303 First Ave., Ottawa, Ont., Canada
Willson, F. E., American Telephone & Telegraph Company, 7 East Clinton, Joliet, Ill.
Yeslin, A., 2739 Augusta Blvd., Chicago 22, Ill.
Yang, T., University of Toledo, Toledo 6, Ohio

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

Wavemeter and Modulation Indicator

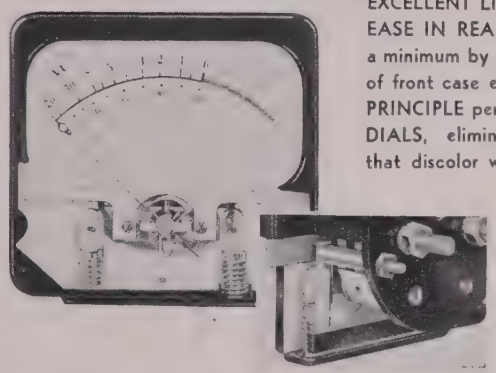
The new Model 180 is a pocket-size control unit complete in itself which is being produced by the **Simpson Electric Co.**, 5216 W. Kinzie St., Chicago, Ill.

Designed for use by hams, ships, police radio, etc., it is an all-purpose instrument which makes it possible to accurately monitor quality of transmission, spot a transmitter at any point on the band desired, and keep a constant check on percentage modulation.

Encased in cast aluminum, the Model 180 wavemeter serves also to plot antenna field patterns, indicate changes in actual radiated power output, and search the region between bands for harmonics and parasitics. Separate coils for the 10-, 20-, 40-, and 80-meter bands and hand-drawn calibration curves are supplied. For coverage of all possible field-strength conditions, the 2-foot antenna can be plugged into the panel jack provided. Range of the instrument covers bands up to and including 420 Mc.

(Continued on page 46A)

New! Burlington
ILLUMINATED INSTRUMENTS



EXCELLENT LIGHT DISTRIBUTION affords EASE IN READING. GLARE REDUCED to a minimum by retaining COMPACT DESIGN of front case extension. REFLECTED LIGHT PRINCIPLE permits use of standard METAL DIALS, eliminating translucent materials that discolor with age and use. BULB REPLACEMENT FACILITATED by removal of single lamp assembly. Two 3.8 volt STANDARD BULBS are used and connected in series.

Available in all ranges 3½" and 4¼" rectangular semi-flush models. Write Dept. I 19 for complete details.

Cutaway views showing positions and connections of lamp assembly.

BURLINGTON INSTRUMENT COMPANY
BURLINGTON, IOWA

Now! Specify KENYON

KENYON one of the oldest names in transformers, offers high quality specification transformers custom-built to your requirements. For over 20 years the KENYON "K" has been a sign of skillful engineering, progressive design and sound construction.

KENYON now serves many leading companies including: **Times Facsimile Corporation, Western Electric Co., General Electric Co., Schulmerich Electronics, Sperry Gyroscope Co., Inc.**

Yes, *electronification* of modern industrial machinery and methods has been achieved by KENYON'S engineered, efficient and conservatively rated transformers.

For all high quality sound applications, for small transmitters, broadcast units, radar equipment, amplifiers and power supplies — Specify KENYON! *Inquire today for information about our JAN approved transformers.*

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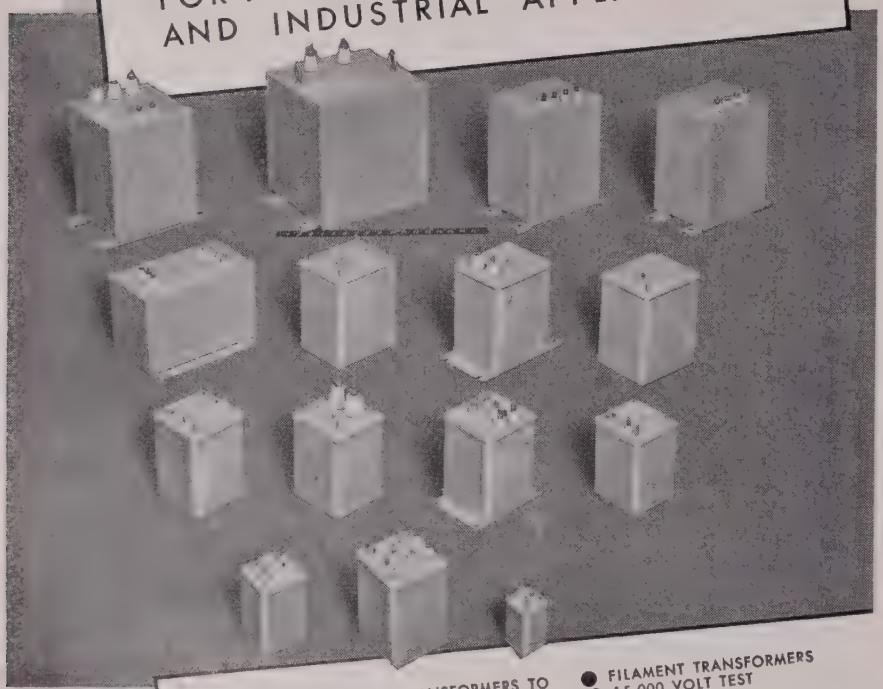
New! All inclusive!

STANDARD LINE OF TRANSMITTER COMPONENTS

FOR AM, FM AND TV—LABORATORY AND INDUSTRIAL APPLICATIONS



INCLUDING—

- PLATE TRANSFORMERS TO 10 KVA
- FILTER REACTORS
- FILAMENT TRANSFORMERS TO 15,000 VOLT TEST
- PLATE FILAMENT TRANSFORMERS LOW VOLTAGE

FEATURING—

- 115/230 VOLT, 50/60 CYCLE SUPPLY
- RUGGED INTERNAL CONSTRUCTION, SUPPORTED CORE STRUCTURE
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- AIEE SURGE TEST ON HIGH VOLTAGE UNITS
- EFFICIENT MAGNETIC AND ELECTRO-STATIC SHIELDING
- UNIFORM STREAMLINED APPEARANCE
- STURDY STEEL CASES

Here is one of the finest and most complete lines of standard transmitter components available today. Built to the same well-known high standards as N·Y·T custom-built units, they bring to the design engineer the full economy of standardized construction. Superbly constructed, inside and out, each unit fully reflects the years of experience that have made the name NEW YORK TRANSFORMER synonymous with quality, integrity and dependability wherever inductive components are used.

WRITE FOR CATALOG

NEW YORK TRANSFORMER CO., INC.
ALPHA, NEW JERSEY

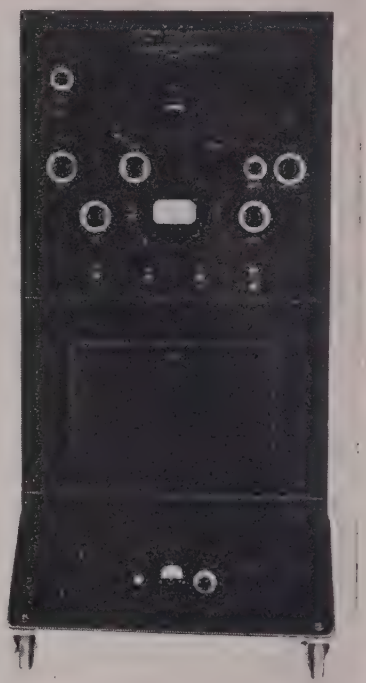
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 45A)

New Test Equipment

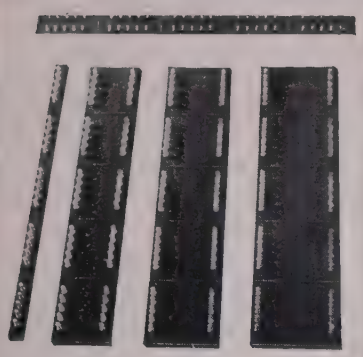
Measurements Corporation, Boonton, N. J., has announced a new television standard signal generator, their Model #90. With a carrier range extending from 20 to 250 Mc, it is said to be the first such really commercial unit to reach the market. Engineering design features include a buffer stage and harmonic operation to provide separation of the output stages from the oscillator, so that the stability will not be disturbed through the coupling system. Modulation of the instrument extends to 5 Mc, assured through the use of band-pass over-coupled circuits. A crystal calibrator within the instrument permits accurate setting of the output signal frequency over the eight bands used to cover the wide range of generated signal. The video modulator provides a standard RMA composite signal, while the oscilloscope provided permits continuous monitoring of the output levels of the keyed dc potentiometer for observing the level of the signal delivered to the test under way. Dual coaxial output connectors are provided, with an attenuator of the balanced mutual-inductance type to afford smooth control of the delivered signal. The unit is mounted on casters for easy portability about the laboratory.



Kay Electric Co., Pine Brook, N. J., has announced that their Mega-Match is now available in a modified design to indicate reflected energy in a band width of 30 Mc anywhere in the spectrum between 10 and 500 Mc. In many applications it

(Continued on page 47A)

Save Time...Speed Assembly with CTC ALL-SET Boards!



On the assembly line and in the laboratory, CTC *ALL-SET* Boards are valuable time-savers.

With Type 1558 Turret Lugs, a new board now offers mounting for miniature components. 1 1/16" wide, 3/32" thick, only. (Type X1401E.)

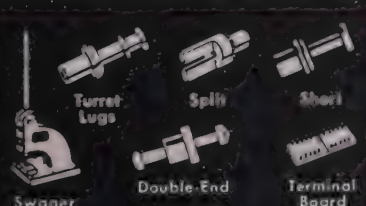
With Type 1724 Turret Lugs, boards come in four widths: ½", 2", 2½", 3" — in 3/32", ⅛", 3/16" thicknesses.

With the addition of the new miniature board, CTC *ALL-SET* Boards now cover the entire range of components.

All boards are of laminated phenolic, in five-section units, scribed for easy separation. Each section drilled for 14 lugs. Lugs solidly swaged into precise position . . . whole board ready for your assembly line.

SPECIAL PROBLEMS

Custom-built boards are a specialty with CTC. We're equipped to handle many types of materials including the latest types of glass laminates . . . many types of jobs requiring special tools . . . and all types of work to government specifications. Why not drop us a line about *your* problem? No obligation, of course.



Custom or Standard The Guaranteed Components

CAMBRIDGE THERMIONIC CORPORATION
456 Concord Avenue, Cambridge 38, Mass.

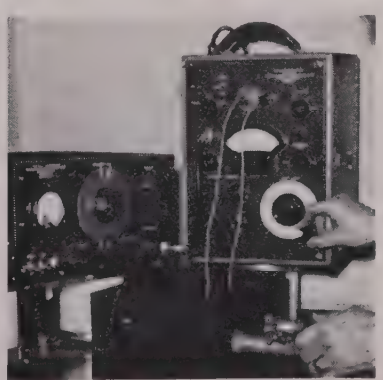
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 46A)

can be used to frequencies as high as 1,000 Mc. This is accomplished by a special coaxial detector. A high-quality relay line is included with the instrument.

Technology Instrument Corp., 1058 Main St., Waltham, Mass., brings forth a radio-frequency model of their renowned Z-angle meter, to make such tests as impedance, phase angle, etc., on antennas and transmission lines, and in general testing of radio frequency equipment. It makes such test possible without complex mathematics and the need for elaborate groupings of many test instruments. Those familiar with the audio-frequency model Z-angle meter will welcome an instrument specifically designed to make the same testing rapidly, at the radio end of the communication spectrum. Detailed technical data is available by addressing a written request to the makers.



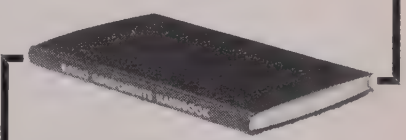
DeMornay Budd, Inc., 475 Grand Concourse, New York, N. Y. have added to their line of waveguide apparatus with a new calorimeter to measure high orders of power in the microwave region. Although measuring average power as high as 500 watts at frequencies reaching 26,500 megacycles the calorimeter will make measurements starting at as low as 5 watts average power, and the accuracy of measurement increases with an increase in the amount of power measured. Accuracies as high as 2 watts in 500 watts are claimed possible for this unit at these extreme ranges and the oigh degree of engineering acumen built into the unit will be appreciated when it is realized that the instantaneous amounts of power can run to millions of watts. Measurement is accomplished by causing a water bath to absorb the entire rf power under test, this

(Continued on page 48A)

A practical compilation of radio-electronic data

RADIO COMPONENTS HANDBOOK

This book was written to fill the gap between the formal text and the general data book. The material is written for the practicing engineer, technician and student, and has been acclaimed by leading engineers and educators as the first practical book on the subject. Fundamental design and application technique together with general components reference data. Invaluable as a practical text and reference volume.



Contents include: General Design, Application and Specification; Cost Considerations; Underwriters; Transformers—power, a-f, r-f; Capacitors —fixed, variable, electrolytic; Resistors — fixed, variable; Speakers; Switches; Wire, Cables, Insulating Materials; Tube and Metallic rectifiers; General Tables and Charts.

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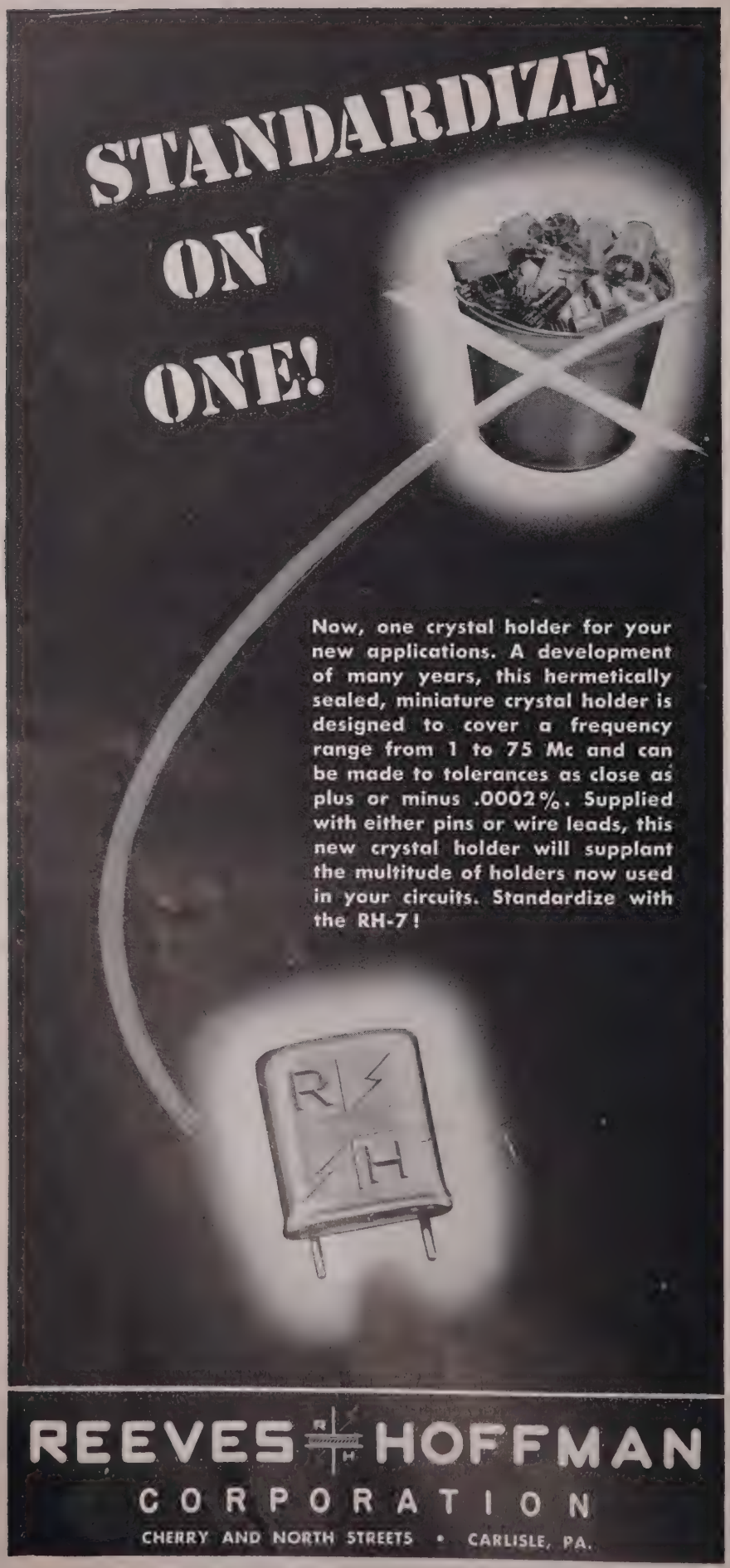
STANDARDIZE
ON
ONE!
Now, one crystal holder for your new applications. A development of many years, this hermetically sealed, miniature crystal holder is designed to cover a frequency range from 1 to 75 Mc and can be made to tolerances as close as plus or minus .0002%. Supplied with either pins or wire leads, this new crystal holder will supplant the multitude of holders now used in your circuits. Standardize with the RH-7!
R H
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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 47A)

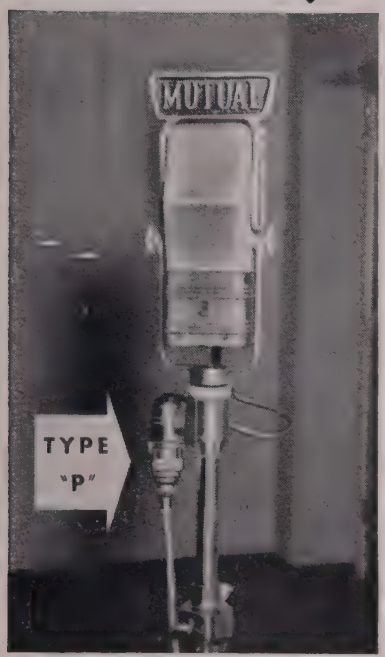
water bath in turn then being cooled through the use of a circulating pump and connection to the external water supply. Accurate flow meters and needle valves enable measurement of the amount of heat sent into the water bath, recirculated in the system by a $\frac{1}{4}$ hp motor actuating a vane-type impeller pump. A higher-powered model is now in process of development.

Tracerlab, Inc., 55 Oliver St., Boston, Mass., has brought forth a new radiation testing meter of the ionization chamber variety, Battery-operated with a life rating of over 1,000 hours to a set of cells with three ranges calibrated on a 3″ meter and a pistol grip, the scope of the instrument is such that the range of beta or gamma rays measured and detected is well below the safe dosage value and well above the amount found in most radioactive laboratories today. The Model SU-iA as it is known is suitable for measurements of both radioisotopes as well as X-ray radiation as low as 50 kilovolts in origin.

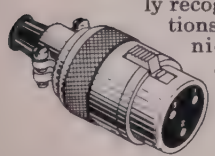
Beta Electronics Co., 1762 Third Ave., New York, N. Y., have a new kilovoltmeter with f.s. ranges of 15/30 and 25/50 kilovolts, and 50 kilohms/volt and 25 kilohms/volt, respectively. Safety of operating personnel is a design feature incorporated in these instruments, the high-voltage test lead being equipped with a lucite handle of good length, making it possible to test circuits while the high voltage is applied thereto. The leads are

(Continued on page 49A)

YOU CAN TELL THE QUALITY OF THE PLUG BY THE EQUIPMENT IT CONNECTS



RCA microphone with Type P3-CG-11S Plug and P3-42 Receptacle on P-41b special curved mounting base in Radio Station KHJ of the Mutual Network in Hollywood.



The Type "P" Series is widely recognized by radio stations and sound technicians everywhere as not only the standard, but the leading series of microphone connectors. Prominent among its many desirable qualities is the patented latchlock which provides positive engagement and requires only the slight pressure of the thumb for release to disconnect. It will not pull apart accidentally.

Stocked or available from such radio parts distributors as Hughes-Peters in Dayton, Specialty Distributing in Atlanta, Lew Bonn in Minneapolis, Almo Radio in Philadelphia and more than 250 others.

For full information on the Type P, ask for Bulletin PO-248. . . And for prices RJC-2. . . Address Department A-377.

SINCE 1915

CANNON ELECTRIC

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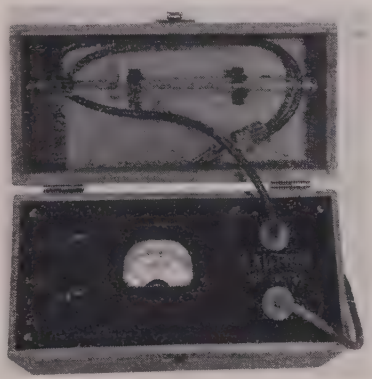
News—New Products

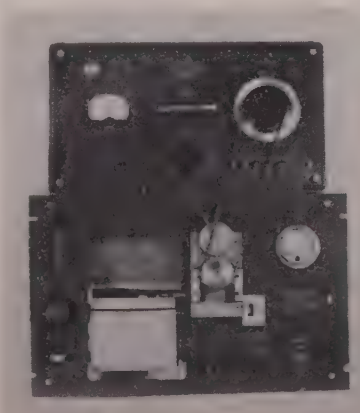
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 48A)

permanently attached to the instrument, so that there is no danger of contact with live wires at this potential. All switching takes place at low voltage, and the panels is protected from any lethal potentials. The input resistance is constant on both ranges, and the meter is a 20-micro-ampere full-scale instrument, for high sensitivity properly shunted to indicate the two ranges enumerated.



Sound Apparatus Co., 233 Broadway, New York, N. Y., has combined their recording sound analyzer with a General Radio Sound Analyzer Model 760-A to make a record on a 4" wide tape record. Complex waveforms are thus interpreted in a visible record with full scale ranges of 20, 40, 60 or 80 db range. The two instruments are mechanically linked to enable rapid analysis of the spectrum or complex waves as the unit eliminates the tedious point-by-point measurement technique, necessary without the use of a continuously recording ink recorder, for this type of laboratory study. As the instrument is portable, it lends itself ideally to field and laboratory use alike. Full data can be had by writing the makers.



Recent Catalogs

• • • A pictorial description in Catalog No. 900 of the complete line of clips and electrical specialties offered by **Mueller Electric Co.,** 1583 E. 31 St., Cleveland 14, Ohio.

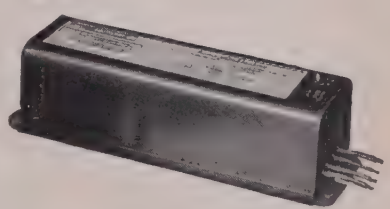
(Continued on page 60A)

What are Your TRANSFORMER SPECIFICATIONS?

Would a slight change from the" standard" electrical specifications improve the performance of your finished product? If so, get in touch with Acme Electric engineers for assistance in designing a "special" transformer from standard parts.

For television, radio, and other electronic applications, Acme produces a wide variety of transformers all with different specifications from standard parts. This means better performance, better quality and often at economy prices.

ENCLOSED TYPES



The dies for making transformers that fit into this enclosed case, alone would cost you thousands of dollars. Acme produces to save you this expense.

Here is a typical air-cooled design which can be produced to meet a variety of applications. Write for Bulletin 168A for further details.

ACME ELECTRIC CORP.
441 WATER ST. CUBA, N.Y.

Acme Electric
TRANSFORMERS

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Familiar with ultra high frequency and micro wave technique.

Experience with electronic digital and/or analog computer research and development program.

Salaries commensurate with experience and ability. Excellent opportunities for qualified personnel.

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C. G. Jones, Personnel Department
Goodyear Aircraft Corporation
Akron 15, Ohio

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

MATHEMATICIANS, ENGINEERS, PHYSICISTS

Men to train in oil exploration for operation of seismograph instruments, computing seismic data, and seismic surveying. Begining salary $250.00 to $300.00 per month depending upon background. Excellent opportunity for advancement determined by ingenuity and ability. The work requires changes of address each year; work indoors and out; general location in oil producing locations. Send resume and include snapshot to National Geophysical Co., Inc., 8800 Lemmon Ave., Dallas 9, Texas.

ELECTRONICS ENGINEER

Well known, 40 year old manufacturer of electrical and electronic instruments wants research engineer experienced in design of radio electronic apparatus at high frequencies, for the development of military and civilian test equipment. Box 542.

(Continued on page 52A)

ELECTRONICS ENGINEER

Senior engineer wanted for Engineering Department of large established, well-known firm, which designs and uses electronic instruments, counters and computing aids extensively for its own operations. Applicants must have degree in Electrical Engineering with Communications major. Graduate study highly desirable. Experience must include two or more years of research or development work in private industry. Location North side of Chicago. Salary open. In reply, please state age, give summary of education, experience and past employers.

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Radio Engineers
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ENGINEERS – ELECTRONIC

Senior and Junior, outstanding opportunity, progressive company. Forward complete résumés giving education, experience and salary requirements to

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ELECTRICAL ENGINEERS

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Address inquiries to Personnel Manager—

Federal Telecommunication Laboratories, Inc.
500 Washington Ave. Nutley, N.J.

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Openings in Pittsburgh

ENGINEER having three or more years experience in radar or television for work on television systems and television receiver research.

ENGINEER or PHYSICIST with experience in underwater acoustics.

PH.D. PHYSICIST with background for working on solid state problems.

ENGINEER or PHYSICIST for work on magnetic circuits and materials.

ELECTRONIC ENGINEER to work on advanced circuit design problems.

ENGINEER or PHYSICIST with three centimeter wave guide experience.

For application address Manager, Technical Employment, Westinghouse Electric Corporation, 306–4th Avenue, Pittsburgh, Pennsylvania

Positions Wanted

(Continued from page 59A)

in television, radio, electronics research or development. Limited Air Force Experience. Ambitious, persevering. Box 195 W.

TECHNICAL EXECUTIVE

Engineering physicist, M.A., Gold medallist, 30, experienced in radio, radar and X-ray, Division manager Montreal branch of European concern wants change to progressive North American concern that can use his talents not necessarily in these fields. Box 203 W.

ELECTRONIC ENGINEER

Currently engaged in production, design and development work for capacitor manufacturer, desires position in electronic industry within Chicago area. B.S.E.E. January 1948 Illinois Institute of Technology. Communications major. Age 25. Married. Two years Navy electronics experience including supervision of Radio Teletype station. Box 204 W.

ELECTRONIC ENGINEER

B.S.E.E. January 1949. College of the City of New York. Age 23. Single. 2 years experience as Navy electronic technician. Location immaterial if near graduate school. Box 214 W.

RADIO ENGINEER

B.S.E.E. June 1949, University of Cincinnati. Age 31. Married. Experience: 2½ Co-op in Quality control and television production; 9 months advanced development high frequency guided missile electronic equipment; 2½ years Army as Communications Chief in Air Forces; 8 years in managerial and executive field. Desires position as research or development engineer with a progressive firm in the eastern or central states. Member of Tau Beta Pi and Eta Kappa Nu. Box 215 W.

TELEVISION ENGINEER

Graduating American Television Institute of Technology, January 1949 with B.S.T.E. Age 28. Married, 1 child. Past supervisory experience. Desires sales or development engineering. Box 216 W.

MICROWAVE ENGINEER

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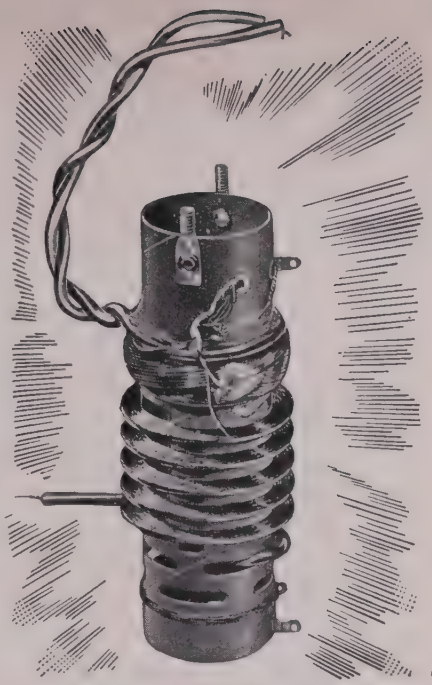

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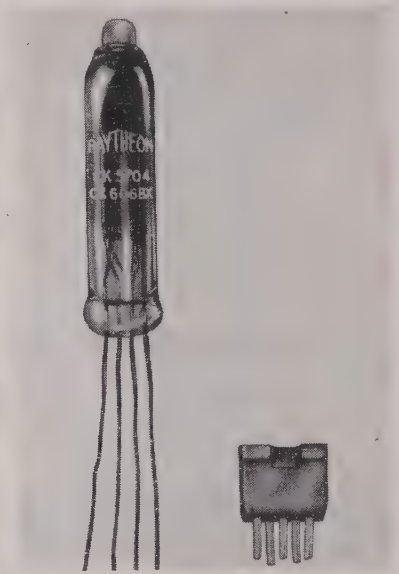
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 49A)

New Tubes

Raytheon Manufacturing Co., 60 E. 42 St., New York, N. Y. widens the scope of their line of sub-miniature tubes with the CK606BX/CK5704, a diode of such small dimensions that its natural resonance is



well above 1,200 Mc. It is similar to one-half of a 6AL5 dual diode of the more conventional-appearing tubes. With a 6.3-volt 150 ma heater, the tube lends itself to rf probes for vtvm applications, or in ufh applications where small size as well as ability to operate at microwave ranges is called for.

Eclipse-Pioneer Division, **Bendix Aviation Corp.**, Teterboro, N. J., has announced a TT-1 ultra-high-frequency diode for television receiver testing, where it is desired to observe sensitivity and to determine the operating range at which it will perform, satisfactorily. The new diode is also applicable to radar receiver sensitivity measurements.

This noise diode was originally developed by RCA, and Bendix is currently making it under license from that organization. It is a noise-generating unit of very wide-band characteristics, so that the sensitivity of the receiver can be ascertained by determining what level above inherent receiving set noise will be needed for producing satisfactory aural and video signals. Laboratory models are now in process of production and the maker will answer all inquiries about their procurement.

(Continued on page 61A)

MICRODIMENSIONAL WIRE & RIBBON FOR VACUUM TUBES

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 60A)

Model TAA-16 Amplifier

The TAA-16, an amplifier useful in the determination of standing-wave voltage ratios when used in connection with square-law detector probes and slotted wave-guides, is available from **Browning Laboratories, Inc.**, Winchester, Mass.

This amplifier has two inputs, selectable by switch for rapid comparison. Operating frequencies are from 500 to 5000 cps, and operation can be wide band or highly selective as needed. The selective network is panel-tuned through the range noted above. The output meter is calibrated directly in standing-wave voltage ratio. Full-scale meter readings are obtained with 15 microvolts at the input under wide band operation, while a 10-microvolt signal will produce this result under selective operation.

The shielding employed permits full gain to be used without disturbance or the 60-cps harmonics generated in the unit.

Description: the TAA-16 is supplied in a cabinet and is suitable for rack mounting; height 9″, width 20″, depth 12″, weight 30½ lbs.

Recent Catalogs

Clarkstan Corp., 11927 W. Pico Blvd., Los Angeles 34, Calif., has issued a new composite catalog describing recent additions to their line of audio-frequency products and associated items. Included are data sheets on their pickup, a sweep-frequency generator, in addition to their sweep frequency record, a pickup scale, and similar items that the engineer particularly interested in audio items will want to have. A copy will be sent upon written request to the company, addressing them with your corporate connection.

Kay Electric Co., 14 Maple Ave., Pine Brook, N. J., has issued bulletins on their products for video testing, each describing in detail the uses to which the unit can be put. These items find application in video set testing and field servicing, and the catalogs and reprints are offered to all in the field who are working in this branch of the art.

National Carbon Co., 60 E. 42 St., New York 17, N. Y., has a booklet listing the carbon brushes of its manufacture. This publication details the methods needed to standardize on types of brushes used in rotating machinery, and the need for such a step, to save large inventories, increase field servicing of units in operation, etc. Ask for Catalog Section B-2106 when writing to the company.

(Continued on page 64A)

Is Your File of Standards Complete?

For your convenience a list of up to date IRE Standards and the ASA Standards sponsored by IRE is given below. The coupon at the bottom may be used for your convenience in ordering standards which you may not have. The standards are punched for 3 ring book and can be permanently filed conveniently.

Current IRE Standards

	Price
1) Standards on Electroacoustics, 1938 Definitions of Terms, Letter and Graphical Symbols, Methods of Testing Loud Speakers. (vi + 37 pages, 6 x 9 inches)....	$0.50
2a) Standards on Electronics: Definitions of Terms, Symbols, 1938. A Reprint (1943) of the like-named section of "Standards on Electronics, 1938." (viii + 8 pages, 8½ x 11 inches)	$0.20
2b) Standards on Electronics: Methods of Testing Vacuum Tubes, 1938. A Reprint (1943) of the like-named section of "Standards on Electrons, 1938." (viii + 8 pages, 8½ x 11 inches)	$0.50
3a) Standards on Transmitters and Antennas: Definitions of Terms, 1938. A Reprint (1942) of the like-named section of "Standards on Transmitters and Antennas, 1938. (vi + 10 pages, 8½ x 11 inches)	$0.20
3b) Standards on Transmitters and Antennas: Methods of Testing, 1938. A Reprint (1942) of the like-named section of "Standards on Transmitters and Antennas, 1938." (vi + 10 pages, 8½ x 11 inches)	$0.50
4a) Standards on Radio Receivers: Definitions of Terms, 1938. A Reprint (1942) of the like-named section of "Standards on Radio Receivers, 1938." (vi + 6 pages, 8½ x 11 inches)	$0.20
4b) Standards on Radio Receivers: Methods of Testing Broadcast Radio Receivers, 1938. A Reprint (1942) of the like-named section of "Standards on Radio Receivers, 1938." (vi + 20 pages, 8½ x 11 inches)	$0.50
4c) Standards on Radio Receivers: Methods of Testing Frequency-Modulation Broadcast Receivers, 1947. (vi + 15 pages, 8½ x 11 inches) ..	$0.50
5a) Standards on Radio Wave Propagation: Definitions of Terms, 1942. (vi + 8 pages, 8½ x 11 inches) ..	$0.20
5b) Standards on Radio Wave Propagation: Measuring Methods, 1942. Methods of Measuring Radio Field Intensity, Methods of Measuring Power Radiated from an Antenna, Methods of Measuring Noise Field Intensity. (vi + 16 pages, 8½ x 11 inches)	$0.50
5c) Standards on Radio Wave Propagation: Definitons of Terms Relating to Guided Waves, 1945. (iv + 4 pages, 8½ x 11 inches)..	$0.20
6a) Standards on Facsimile: Definitions of Terms: 1942. (vi + 6 pages, 8½ x 11 inches) ...	$0.20
6b) Standards on Facsimile: Temporary Test Standards, 1943. (iv + 8 pages, 8½ x 11 inches) ..	$0.20
7) Standards on Piezoelectric Crystals: Recommended Terminology, 1945. (iv + 4 pages, 8½ x 11 inches) ...	$0.20
8a) Standards on Television: Methods of Testing Television Transmitters, 1947. (vi + 18 pages, 8½ x 11 inches) ...	$0.75
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11) Standards on Antennas: Methods of Testing, 1948. (vi + 18 pages, 8½ x 11 inches) ..	$0.75
Normas Sobre Receptors de Radio, 1938.* A Spanish-language translation of "Standards on Radio Receivers, 1938," by the Buenos Aires Section of The Institute of Radio Engineers. (vii + 64 pages, 6 x 9 inches) Two Argentine Pesos (Postpaid)	

* *Not carried in stock at IRE Headquarters in New York. Obtainable only from Señor Domingo Arbó, Editor of Revista Telegrafica, Peru, 165, Buenos Aires, Argentina.*

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INDEX AND DISPLAY ADVERTISERS

Section Meetings 34A
Student Branch Meetings 40A
Membership 41A
Positions Open 50A
Positions Wanted 58A
News-New Products 45A

DISPLAY ADVERTISERS

Acme Electric Corp. 49A
Aerovox Corp. 26A
Aircraft Radio Corp. 42A
American Phenolic Corp. 38A
Amperex Electronic Corp. . . Cover II
Andrew Corporation 40A
Arnold Engineerings Co. 5A
Arrow Electronics Inc. 59A
Astatic Corp. 34A

Barker & Williamson 37A
Bell Telephone Labs. 24A
Bendix Aviation Corp. (Scintilla Div.) 3A
Bendix Aviation Corp. (Radio Div.) 52A
W. J. Brown 62A
Bud Radio, Inc. 44A
Burlington Instrument Co. 45A

Cambridge Thermionic Corp. . . 47A
Cannon Electric Development Co. 49A
Capitol Radio Engineering Inst. 44A
Centralab 22A
Chicago Transformer 20A
Cleveland Container Co. 59A
Sigmund Cohn Corp. 60A
Communications Equipment Co. 39A
E. J. Content 62A
Cornell-Dubilier Electric Corp. Cover III
Crosby Labs. 62A

Dial Light Co. of America 53A
Allen B. DuMont Laboratories 8A, 33A

Eitel-McCullough, Inc. 63A
Electrical Reactance Corp. 25A
Electro-Motive Mfg. Co., Inc. 21A
Erie Resistor Corp. 16A

Federal Telecommunication Labs. 50A
William L. Foss 62A

General Aniline & Film Corp. . . 35A
General Electric Co. 19A, 31A
General Radio Company . . . . Cover IV
Paul Godley 62A
Goodyear Aircraft Corp. 50A
H. L. Gordon 62A
Samuel Gubin 62A

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Eugene Mittelmann 62A
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New York Transformer Co., Inc. 46A

Ohmite Mfg. Co. 29A

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Philco Corp. 52A
Premax Products 43A

Radio Corp. of America . . 32A, 51A
Reeves-Hoffman Corp. 48A
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Sherron Electronics Co. 4A
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Sperry Gyroscope Co., Inc. 52A
Sprague Electric Co. . . . 10A & 11A
Stackpole Carbon Co. 30A

Technical Advertising Associates 47A
Technical Materiel Corp. 62A
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Tektronix, Inc. 41A
Transradio, Ltd. 54A
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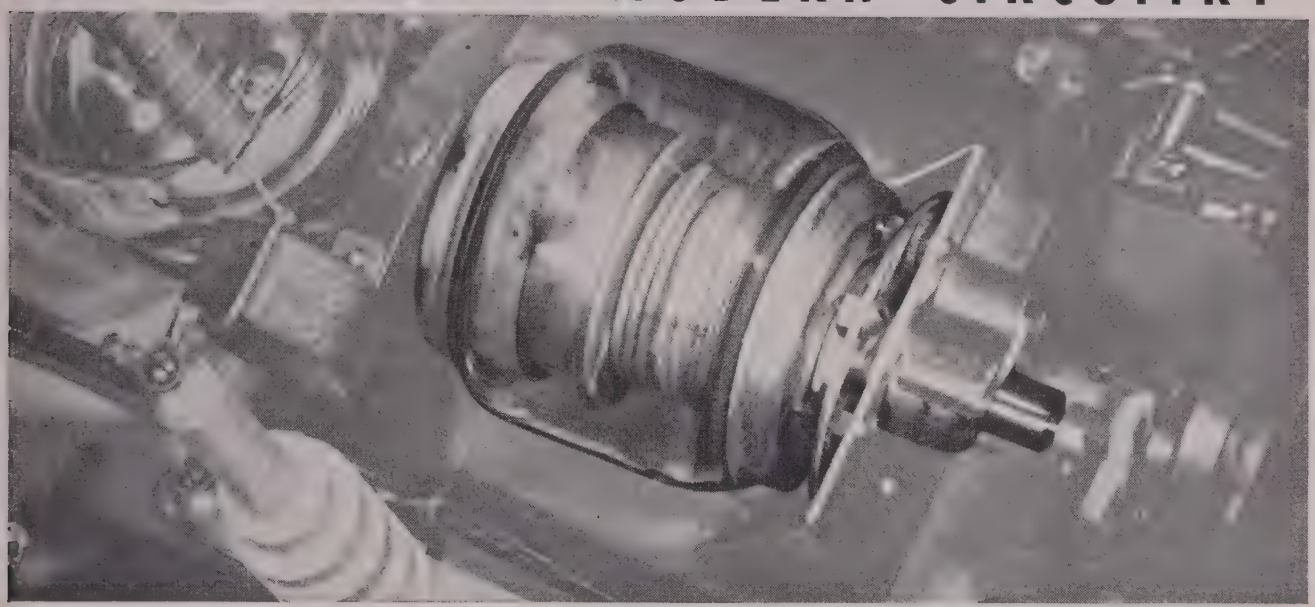

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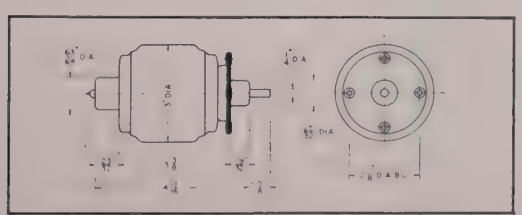

- Structural rigidity eliminates electro-mechanical vibration.
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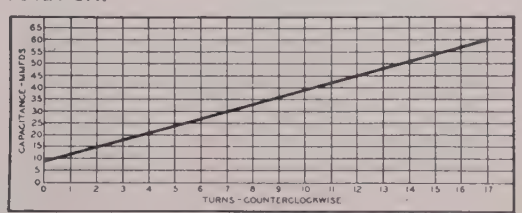

- Low temperature coefficient. Negligible change in capacitance due to temperature variance. (.004 mmfd. per degree cent.)

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Parallel	20-120 mmf.	20-KV	80 amp.
Split-stator	5-30 mmf.	40-KV	40 amp.
VVC4-60-20			
Parallel	40-240 mmf.	20-KV	160 amp.
Split-stator	10-60 mmf.	40-KV	80 amp.

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CARRIER FREQUENCY: 300 to 1000 megacycles.

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OUTPUT IMPEDANCE: 50 ohms.

MODULATION: SINEWAVE: 0—30%, 400, 1000 or 2500 cycles. PULSE: Repetition—60 to 100,000 cycles. Width—1 to 50 microseconds. Delay—0 to 50 microseconds. Sync. input—amplifier and control. Sync. output—either polarity.

DIMENSIONS: Width 26", Height 12", Depth 10".

WEIGHT: 125 pounds including external line voltage regulator.

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 61A)

Custom-Built Miniature Stabilizer

Among the new VR-6000 line of custom-built voltage stabilizers, a miniature 5-watt unit, which has been engineered specifically for building into electronic equipment, is being produced by **Raytheon Mfg. Co.**, 60 E. 42 St., New York 17, N. Y.

This 5-watt stabilizer operates at an input voltage of 95 to 130 volts ac, 60 cps, single phase, with an output of 120 volts stabilized to ±0.5%.

A bulletin describing the complete VR-6000 voltage stabilizer line is available from Raytheon's Product Information Office, Waltham 54, Mass.

Automatic Dehydrator

Andrew Corporation, 263 E. 75 St., Chicago, Ill. announces an automatic dehydrator for use with installations of coaxial lines feeding antennas.

Motor-driven and self-reactivating, the unit is operated at a low line pressure, supplying dry air for a 4-hour period, the next 2 hours being used to reactivate and cool the drying agent. Because of simplicity of design and elimination of formerly included complex parts, now found unnecessary by redesign, the unit will serve many years as a trouble-free accessory to the broadcast industry.

FM Receiver for Buses

General Electric Co., Syracuse, N. Y. has entered the mobile entertainment field, with the introduction of the all-steel, dual-limiter FM Bus Receiver, powered by a 12-volt bus battery and vibrator power supply.

The receiver is designed to work with 6½" loudspeakers, which are mounted in the bus in multiple installations, according to the size of the vehicle. Mobile bus entertainment is a field that the FM broadcaster is taking to warmly, on the theory that it provides an otherwise untapped audience which has nothing to do but listen while riding, thus affording higher-than-average attention to the commercials interspersed between entertainment. Tests have proved the new set highly satisfactory in operation at a demonstration at the American Transit Association at Atlantic City.

Recent Catalogs

• • • A brochure describing a completely reengineered line of marine radiotelephones that cope with the majority of problems encountered in this field of communication, by **Rex Bassett, Inc.,** Bassett Bldg., Ft. Lauderdale, Fla.

• • • The Rider PA Manual, 2024 pages of material covering the products of 147 manufacturers, plus a "How It Works" book describing the theory of the special circuitry found in numerous p-a systems, is on sale for $18.00, by **John F. Rider Publisher, Inc.,** 404 Fourth Ave., New York, 16, N. Y.

• • • A folder containing the latest technical information regarding co-ax air-spaced articulated rf cables for all purposes of research and production where extremely low capacitance and attenuation values are essential, by **Transradio, Ltd.,** 138A, Cromwell Rd., London, S.W. 7, England.

• • • On points to consider in determining solder grade and size for a given job, melting points and feet per lb of various sizes and grades, together with other information of value to solder users, by **Division Lead Co.,** Dept. 200, 836 W. Kinzie St., Chicago 22, Ill.

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Airtron, Inc., Linden, N. J. Flexible and rigid waveguides, wavematch switches and coaxial cables and aircraft ignition shielding.	291
Alden Products Co., Brockton, Mass. Facsimile equipment.	320 & 321
Allegheny Ludlum Steel Corp., Pittsburgh, Pa. Metals, Core Materials and Magnets.	47 & 48
Allied Control Company, Inc., New York, N. Y. Relays.	280
Alpha Metals, Inc., Brooklyn, N. Y. Tri Core Rosin filled solder, Tri Core "Energized" rosin filled solder, Tri Core leak pruf acid filled solder.	207
Altec Lansing Corp., New York, N. Y. Loudspeakers, amplifiers, transformers, radio tuners, Intermodulation Test Equipment and Microphones.	B
American Lava Corp., Chattanooga, Tenn. Ceramic parts for radio and wire communications, television and radar, electronic components, control equipment industrial heating devices.	55
American Phenolic Corp., Chicago, Ill. Radio components, Coaxial cable, rf connectors, television antennas, AN connector, industrial sockets and connectors, Plastics.	111 & 112
Amperex Electronic Corp., Brooklyn, N. Y. Transmitting, Industrial, high power, special purpose, electromedical, radiation counter, etc.,—tube types.	10 & 11
Amplifier Corp. of America, New York, N. Y. Magnetic Tape Recorders and accessory equipment, direct coupled amplifiers, regulated power supplies.	259
Arnold Engineering Company, Chicago, Ill. Powdered Molybdenum Permalloy and Deltamex cores, sintered and cast Alnico, Cunico, Cunife, and other permanent magnet materials.	47 & 48
Antara Products, New York, N. Y. Carbonyl Iron Powder for use in cores and coils.	27 & 28
Arrow Electronics, Inc., New York, N. Y. Television Assembly's projection television kit and set plus individual circuits and components for this unit.	314
Astatic Corporation, Conneaut, Ohio Phonograph pickups, pickup cartridges, microphones, recording heads and accessories.	219
Atomic Instrument Co., Boston, Mass. Nuclear Measurement Apparatus.	335
Audak Company, New York, N. Y. Electronic recorders and reproducers.	43
Audio Development Company, Minneapolis, Minn. Transformers, Amplifiers, Filters, Jacks, Plugs, and Patch Cords, Audiometers.	205
Audio Devices, Inc., New York, N. Y. Audiodiscs (recording discs) Audiopoints (recording and playback points).	233
Audio Engineering, New York, N. Y. Magazines.	94A
Audio Equipment Sales, New York, N. Y. Call letter plates, the Audio rule, jack strips, plattertags, low-voltage filtered power supplies, line equalizers, jacks, plugs and patch cords.	A
Automatic Electric Sales Corp., Chicago, Ill. Relays, stepping switches, and other telephone type remote control components.	265
Ballantine Labs., Inc., Boonton, N. J. Sensitive Electronic voltmeters, Geiger-Mueller Counter Tubes.	100
Barker & Williamson, Inc., Upper Darby, Pa. Test Equipment, Coils, Capacitors and Components.	O
Barnes & Noble, Inc., New York Technical Books.	315 & 316
Barry Corporation, Cambridge, Mass. Vibration and Impact Isolators, standard aircraft mounting bases.	293
Bendix Aviation Corp., Eclipse-Pioneer Div., Baltimore, Md. Special Purpose Tubes, Synchros, Small Servos, Gyros.	15, 16, 17
Bendix Aviation Corp. (Radio Div.), Baltimore, Md. Type NA-3 VHF Omni-Range Receiver, Type TA-18 VHF Transmitter, Type ARN-6 (Commercial Equivalent), Type TG-18 Fixed Station Transmitter.	15, 16, 17
Bendix Aviation Corp., Scintilla Magneto Div., Sidney, N. Y. Electrical Connectors, Electric Filters, Plastics, Bus-K-Nects, Ceramics, switches and radio shielding.	15, 16, 17
Bendix Aviation Corp., Red Bank Div., Red Bank, N. J. Dynamotors, Regulated Dynamotors, Fractional H.P. Motors.	15, 16, 17
Berkeley Scientific Co., Richmond, Calif. Nuclear Instruments, Meters.	333
Bird Electronic Corp., Cleveland, Ohio RF Wattmeters and terminations, coaxial switches, VHF and UHF Antennae and filters.	268
Boonton Radio Corp., Boonton, N. J. 202-B FM Signal generator, 203-B Univerter, 160-A and 170-A Q-Meters, 211-A Signal Generator, 140-A Beat Frequency Generator.	277 & 278
W. H. Brady Co., Milwaukee, Wis. "Quik-Label" self adhesive wire markers, name plates, inspection labels, terminal markers, printed roll tapes.	301
William Brand & Co., New York, N. Y., Chicago, Ill. Varnished and Plastic Electrical Tubings and Sleevings. Plastic insulated Hook-Up and Hi Voltage Wires and Cables.	84B & 85
British Industries Corp., New York, N. Y. Ersin Multicore Solder, Garrard Record Changers.	274
Brooks & Perkins, Inc., Detroit, Mich. Deep drawn magnesium radio and radar boxes and covers, misc. stampings, innumerable fabricated mfg. parts pertaining to aircraft and airborne equip.	122

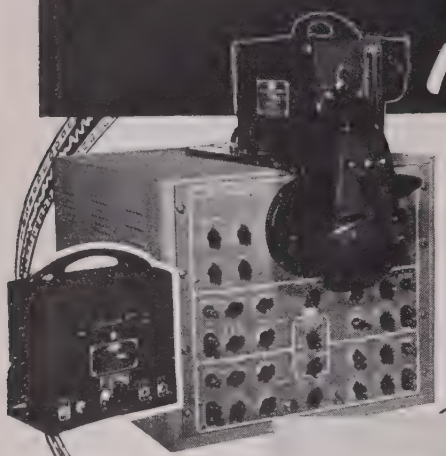
(Continued on page 6A)

PROCEEDINGS OF THE I.R.E., February, 1949, Vol. 37, No. 2. Published monthly in two sections by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price $2.25 per copy. Subscriptions: United States and Canada, $18.00 a year; foreign countries $19.00 a year. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

Table of contents will be found following page 32A

For permanent oscillograph records . . .

it's DU MONT all the way!

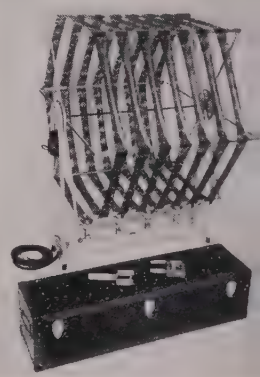


START with Type 314 Oscillograph-record Camera. Especially designed for cathode-ray oscillograph photography. Maximum convenience. Either single-image or continuous recording. Variable speed, electronically controlled. Cat. No. 1366-E, with f/1.5 lens, $1,155.00. Cat. No. 1217-E, with f/2.8 lens, $980.00.

Or with Type 271-A Oscillograph-record Camera (not illustrated). Single-image. Fixed-focus, f/3.5 lens. Cat. No. 1216-E, with mounting, $162.50.

DEVELOP your films with Type 2512 Motor-driven Processing Unit. Utterly simple. Accommodates up to 100 feet of 35mm. film. Cat. No. 1372-E, $231.00.

FINISH with Type 2514 Portable Drying Rack. Holds up to 200 feet of 35 mm. film. Motor-driven. Provided with heater. Easy rewinding. Unit may be folded up. Carrying case supplied. Cat. No. 1375-E, $232.00.



DU MONT CATALOG ITEMS . . .

HIGH AND LOW VOLTAGE OSCILLOGRAPHS: Amplifier frequency response selectable from d-c to 10 mc. Writing rates up to and exceeding 400 inches/microsecond. Deflection factors as low as 0.01 rms volt/inch. Prices from $127.20 to $6,073.75.

OSCILLOGRAPH POWER SUPPLIES: Up to 25,000 volts output for application as final accelerating potential to cathode-ray tubes.

PROJECTION LENS: Projects oscillograph traces on screen up to 30 feet distant. Excellent for demonstrations and lectures. Applicable to high-voltage oscillographs. Type 2542, Cat. No. 1431-E, $103.50.

VOLTAGE CALIBRATOR: For quantitative measurements. Operates with any oscillograph. Type 264-A, Cat. No. 1240-A, $39.50.

ELECTRONIC SWITCH: Provides a time-sharing system for oscillograph presentation of two separate traces. Type 185-A, Cat. No. 1072-A, $105.00.

LOW-FREQUENCY LINEAR TIME-BASE GENERATOR: Du Mont Type 215 accessory extends low-frequency range of the time-base of oscillographs. Cat. No. 1189-A, $215.00.

SPECIALIZED EQUIPMENT: Type 279 Dual-beam Cathode-ray Oscillograph presents two entirely separate traces. Cat. No. 1386-E, $1,294.50. • Type 275-A Cathode-ray Polar Coordinate Indicator employs a circular time-base. Cat. No. 1250-E, $390.00. • Calibrated scales; constant-voltage transformer; transducers; magnetic shields, etc.

DU MONT CATHODE-RAY TUBES: A full line of cathode-ray tubes. A choice of phosphors suited to your particular needs.

▶ In oscillography, Du Mont can supply you with the *tube*, the *oscillograph*, the *accessory*. Note partial list of standard items.

And if your oscillograph needs are *extremely special*, even to the extent of exceeding the broad range of our standard equipment, Du Mont can now place at your disposal the services of our Instrument Model Shop which is equipped to design, develop and manufacture non-standard cathode-ray equipment, or to modify existing equipment and designs. Consult us.

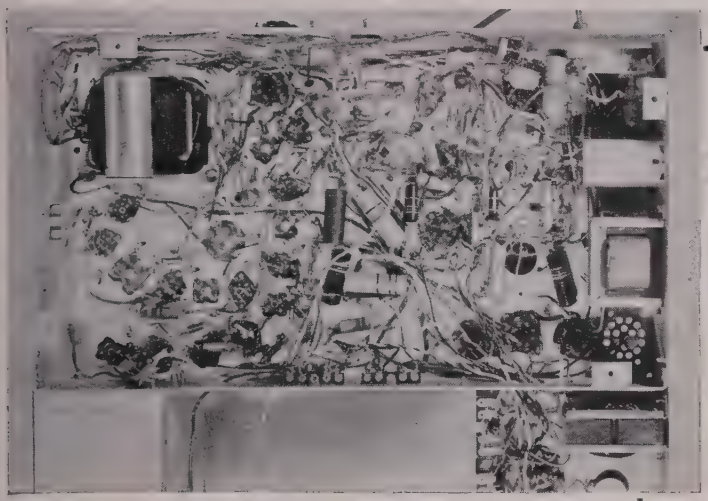
▶ ***Detailed literature on request. Equipment demonstrations arranged—no obligation.***

© ALLEN B. DU MONT LABORATORIES, INC.

DU MONT for Oscillography

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U.S.A.

IT PAYS * Hi-Q TO SPECIFY COMPONENTS for Hi-Quality T. V. Performance



RCA Victor television receiver Table Model 8T241 uses many **Hi-Q** *capacitors for Uniform, Dependable reception.*

● Not only RCA Victor, but practically every manufacturer of television sets looks to **Hi-Q** Electrical Reactance Corporation for components of *Dependable* quality ...*Precision* tested and *Uniform* capacity.

Today's tremendous demand for high quality **Hi-Q** components is being met at three (3) modern plants equipped with the most modern machines helping supply the needs of the fast growing electronics industry.

Our competent engineering staff is available for consultation with your engineers in the design of newly developed circuits.

Booth No. 54 at I. R. E.

A FEW OF THE COMPANIES USING Hi-Q ELECTRONIC COMPONENTS

STROMBERG-CARLSON
ZENITH RADIO
RCA VICTOR
Westinghouse RADIO TELEVISION
Sparton
CROSLEY
Bendix Radio
Motorola
Tele-tone
Packard-Bell
Admiral
DUMONT
GENERAL ELECTRIC

Hi-Q components are specified by over 200 leading manufacturers. Space does not permit listing all of our valued customers.

Hi-Q COMPONENTS BETTER 4 WAYS

PRECISION Tested step by step from raw material to finished product. Accuracy guaranteed to your specified tolerance.

UNIFORMITY Consistency of quality is maintained over entire production through continuous manufacturing control.

DEPENDABILITY Tolerances also factor in terms of user satisfaction . . . Years after years of trouble free performance. Our Hi-Q makers can't do better.

MINIATURIZATION The smallest BIG VALUE components in the world make possible space saving factors which reduce your production costs . . . increase your profits.

Hi-Q *Electrical Reactance Corp.*
FRANKLINVILLE, N. Y.

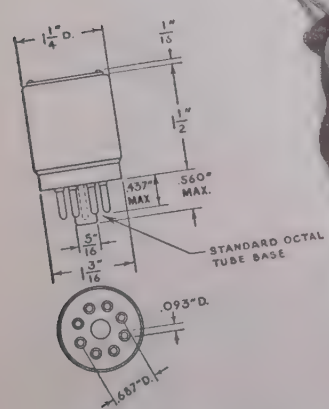
Plants: FRANKLINVILLE, N. Y.—JESSUP, PA.—MYRTLE BEACH, S. C.
Sales Offices: NEW YORK, PHILADELPHIA, DETROIT, CHICAGO, LOS ANGELES

Space limitations in communications equipment call for a new form factor in crystal temperature stabilizers. Again, Bliley is first with the answer. The new TCO-1 is a miniaturized crystal oven which provides the high temperature stability necessary for precision performance. The TCO-1 employs a Bliley type BH6 crystal unit which is mounted internally. With this combination, frequency stability may be maintained within .0001% over a wide ambient temperature range. This crystal oven, with type BH6 crystal unit, is supplied at any frequency in the range 1—100 mc.

OPERATING CHARACTERISTICS

1. **Temperature stability ±2°C from minus 50°C to plus 70°C.**
2. **Operating temperature: 75°C.**
3. **Rating: 6.3 volts, 5.5 watts.**

DIMENSIONAL DATA



Bliley CRYSTALS

BLILEY ELECTRIC COMPANY

What to SEE at the 1949 Radio Engineering Show

Directory of 200 Exhibits

(Continued from page 1A)

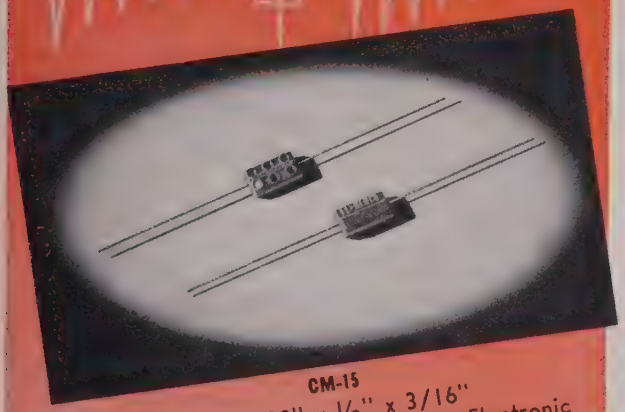
Firm	Booth
Browning Labs., Inc., Winchester, Mass. Cathode Ray Oscilloscopes, Timers, FM-AM Tuners, Frequency Meters.	G
Brujac Electronic Corp., New York, N. Y. High Voltage Power Supplies, Electronic Microammeters, Impedance bridges, Composite Video Signal Generators, Video Sweep Generator.	239, 240
Brush Development Co., Cleveland, Ohio Recording Equipment, Industrial Instruments and acoustic devices.	F
Bud Radio, Inc., Cleveland, Ohio Sheet Metal Housings, Variable Condensers, Air-Wound Coils, plugs, jacks, chokes, and other misc. radio and electronic components.	231
Bundy Tubing Co., Detroit, Mich. Copper Brazed steel tubing for antennas. Also antennas made by various manufacturers from bundyweld tubing.	123
Burlington Instrument Co., Burlington, Iowa AC and DC Electrical Indicating Instruments, AC and DC portable instruments, Voltage regulators, synchronizers.	229
Bussmann Manufacturing Company, St. Louis, Mo. Fuses and Fuse Holders for the radio and electronic trade.	309
Caldwell-Clements, Inc., New York, N. Y. "Tele-Tech" television and telecommunications engineering magazine and "Radio and Television Retailing" merchandising and servicing trade magazine.	286
Cambridge Thermionic Corp., Cambridge, Mass. Terminals, Terminal Board Assemblies, Electronic Hardware, IF and RF Chokes and Coils, Earth Shock and Underwater Pressure Gauges.	288
Camburn, Inc., Woodside, N. Y. TV and FM Antennas and Accessories, Auto Antennas.	213
Canadian Marconi Co., Montreal P. Q., Canada Nuclear instruments, scalar kick-sorter and component assemblies.	336
Cannon Electric Development Co., Los Angeles, Calif. Connectors-Multiple Contact Electronic.	210
Capitol Radio Engineering Inst. Inc., Washington, D. C. Complete library of CREI Text material.	267
Carter Parts Company, Chicago Ill. Electrical Controls.	255
Centralab, Div. of Globe Union, Inc., Milwaukee, Wis. Printed Electronic circuits, ceramics, capacitor, control switches, components.	234 & 235
Chatham Electronics Corp., Newark, N. J. Tubes, Radiological and Chemical Display.	120 & 121
Chicago Rivet & Machine Co., Bellwood, Ill. Rivets, Steel and Brass, Tubular and Split, Automatic Rivet Setting Machines.	214 & 215
C. P. Clare & Co., Chicago, Ill. Relays, including hermetically sealed relays, stepping switches, lever keys, push keys, turn keys.	258
Clarostat Mfg. Co., Inc., Dover, N. H. Controls (wire wound and carbon) wire wound resistors, power rheostats, television parts.	221

Firm	B
Cleveland Container Company, Cleveland, Ohio A complete line of Cosmalite coil forms and television deflection yoke sleeves.	
Sigmund Cohn Corp., New York, N. Y. Radio tube filament and grid wires, platinum metals and their alloys, electroplated wires, rhodium plating solution, wollaston process wire.	
Collins Radio Co., Cedar Rapids, Iowa Airborne transmitters and receivers, Broadcast AM and FM transmitters and speech equipment, specialized mechanical accessories for radio equipment, VHF ground station transmitters and receivers.	
Communication Products Co., Inc., Keyport, N. J. Coaxial Aircore Transmission Line and accessories. Rotary Band switches, Antennas for Mobile Service, Dehydrators.	70
Communications, New York, N. Y. Communications magazine.	
Condenser Products Co., Chicago, Ill. Capacitors, power supplies, pulseforming networks.	
Continental Carbon, Inc., Cleveland, Ohio Nobleloy Metal Film, Carbon Film, Carbomite resistors, suppressors, wire wound resistors, low power capacitors.	
Cornell-Dubilier Electric Corp., So. Plainfield, N. J. Capacitors.	72
Daven Co., Newark, N. J. Audio, video and RF attenuators, rotary switches, measuring equipment, resistors.	94B
Bryan Davis Pub. Co., Inc., New York, N. Y. Communications Magazine, Service magazine	
DeMornay Budd, Inc., New York, N. Y. Microwave Test equipment and plumbing, radar components, microwave spectroscopy components.	
Tobe Deutschmann Corp., Norwood, Mass. Capacitors, Filters, Test and Measuring Equipment.	
Dial Light Co. of America, Inc., New York, N. Y. Pilot light assemblies, warning signal lights, sockets for min. bayonet and candelabra screw base lamps.	
Distillation Products, Inc., (Eastman Kodak Co.) Rochester, N. Y. High vacuum tube exhaust equipment, high vacuum rotary coater for aluminizing cathode ray or other tubes.	227
Allen B. DuMont Labs., Inc., Clifton, N. J. Cathode-ray instruments, cathode-ray tubes.	12
Allen B. DuMont Labs., Inc., Clifton, N. J. Television transmitting and studio equipment.	24
Eitel-McCullough, Inc., San Bruno, Calif. Transmitting type vacuum tubes and vacuum capacitors, vacuum switches.	
El-Tronics, Inc., Philadelphia, Pa. LS-100 Decade Scaler, LS64 Binary Scaler, RM4-Counting Rate Meter, SM 3 Portable GM Survey Meter, LS-1 Non Scaling Counter.	
Electrical Reactance Corp., Franklinville, N. Y. Ceramic capacitors, resistors, choke coils.	

(Continued on page 22A)

NO OSCILLATING CIRCUIT IS BETTER THAN ITS CAPACITOR(S)

NO CAPACITOR IS BETTER THAN EL-Menco

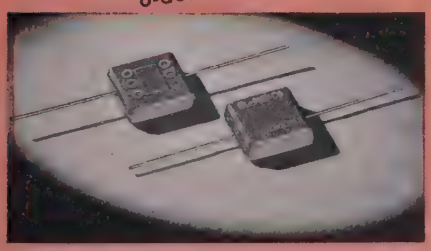


This is why more and more manufacturers of Radio, Electrical and Electronic equipment are turning to EL-MENCO. Engineers specify EL-MENCO when they want small size, high capacity and unquestioned performance in capacitors.

Each tiny EL-MENCO capacitor does the job it was designed to do, with absolute accuracy and complete dependability. When you want to protect your products' reputation for performance perfection — specify EL-MENCO for capacitors that really satisfy.

CM-15

Actual Size 9/32" x 1/2" x 3/16"
For Television, Radio and other Electronic Applications
2 — 420 mmf. cap. at 500v DCA
2 — 525 mmf. cap. at 300v DCA
Temp. Co-efficient —50 parts per million per degree C for most capacity values.
6-dot color coded.



CM-30

Available in A, B, C, D and E Characteristics. Minimum tolerance (A and B) 5%. Minimum tolerance (C, D, E) 1%. 470 to 6,200 mmf. cap. at 500 DC working voltage*. 6-dot color coded.

CM-40

Available in A, B, C, D and E Characteristics. Minimum tolerance (A and B) 5%. Minimum tolerance (C, D ,E) 1%. 3,300 to 7,500 mmf. cap. at 500 DC working voltage*. 8,200 to 10,000 mmf. cap. at 300 DC working voltage*. 6-dot color coded.

ARCO ELECTRONICS, INC., 135 Liberty Street, New York, N. Y.
Sole agent for jobbers and distributors in U. S. and Canada.

THE ELECTRO MOTIVE MFG. CO., INC.
WILLIMANTIC CONNECTICUT

Write on your firm letterhead for Catalog and Samples

***Can be made in other capacity values and voltage ratings**

Foreign Radio and Electronic Manufacturers communicate direct with our Export Dept. at Willimantic, Conn. for information.

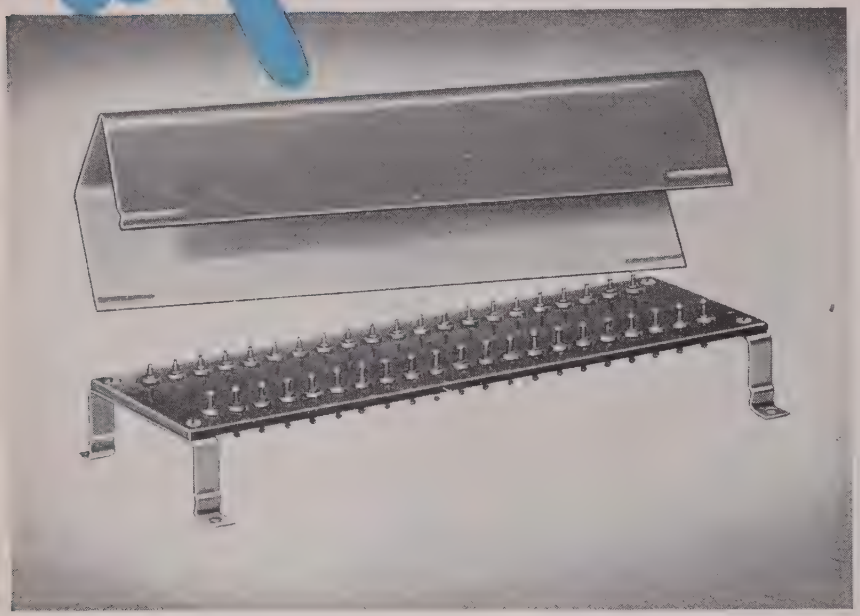
MOLDED MICA

EL-Menco CAPACITORS

MICA TRIMMER

You, Too, can get results like this

...WHEN C.T.C.'s CUSTOM ENGINEERING SERVICE HANDLES YOUR PROBLEMS

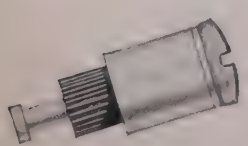


A snap-on covered multi-contact terminal board assembly constructed of approved materials to meet a client's special requirements

When one of our customers approached us with a terminal board problem a short time ago, the requirements were such that no standard board could be found to do the job.

And that's where C.T.C.'s Custom Engineering Service went to work. The result: the board you see above.

This is just one of many examples in which C.T.C. Custom Engineering has produced results for electronic and radio manufacturers. We are equipped to produce assembled terminal boards of almost any description using any approved material . . . terminal lugs designed and produced to your special requirements in any needed quantity . . . coils and chokes of whatever capacities and characteristics you may need.



Combination lug. Screw on top . . . solder terminal below. Designed as a rugged swaged terminal for top & bottom wiring applications.

C.T.C. is prepared to meet any special requirements you may have for terminal lugs.

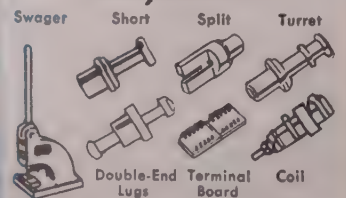
Our engineers will gladly design lugs to fill your needs and produce them in quantity.

Hi Q oscillator coil — made to close tolerances mounts directly on band switch.

C. T. C. has helped many manufacturers in designing special coils and chokes to meet individual conditions. Can we be of service to you? We'll see your problem through from design board to production.

See us at Booth 288 at the IRE Exposition, Grand Central Palace, March 7-10. A C.T.C. Engineer will be glad to discuss problems concerning electronic components.

Custom or Standard The Guaranteed Components



CAMBRIDGE THERMIONIC CORP.
456 Concord Ave., Cambridge 38, Mass.

What to SEE at the 1949 Radio Engineering Show

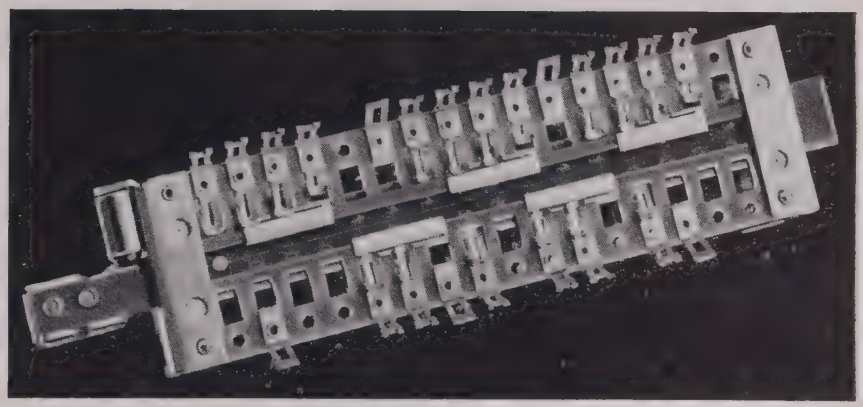
Directory of 200 Exhibits

(Continued from page 6A)

Firm	Booth
Electro-Tech Equip., Co., Inc., New York, N. Y. Laboratory and Portable Test instruments, Panel and Switchboard Instruments, Pyrometers and associated equipment, service instruments.	297 & 298
Electro-Voice, Inc., Buchanan, Mich. Microphones and phonograph pickup cartridges.	272
Electronic Mechanics, Inc., Clifton, N. J. Fabricated and molded electrical insulation parts of "Mykroy," a glass-bonded mica.	319
Electronic Tube Corp., Philadelphia, Pa. 4-Channel Cathode Ray oscilloscope, 2-Channel cathode ray oscilloscope with plug-in amplifiers, high gain DC amplifier.	271 & 272
Electronics, New York, N. Y. Electronics Magazine.	200
Erie Resistor Corp., Erie, Pa. Ceramic Condensers, Button Silver Mica Condensers, molded plastic parts for radio and television application.	91
Fairchild Recording Equipment, Corp., Whitestone, N. Y. Professional recording equipment and transcription equipment including a new professional tape recorder.	D
Fansteel Metallurgical Corp., North Chicago, Ill. Tantalum, Tungsten, Molybdenum, Electronic Tube Components, Selenium rectifiers, electrical contacts.	292
Federal Telephone & Radio Corp., Clifton, N. J. Television transmitter link and other broadcast equipment, transmitter tubes, telephone carrier equipment, radio aircraft equipment.	29–34
Ferris Instrument Co., Boonton, N. J. Complete line of Ferris instruments, with new features not shown before.	1, 2, 3
Freed Transformer Co., Inc., Brooklyn, N. Y. Transformers, reactors, wave filters, laboratory test equipment.	103
Furst Electronics, Chicago, Ill. Wow meter for microgroove turntables and wire recorders. Various types of regulated Power supplies.	R
General Ceramics & Steatite Corp., Keasbey, N. J. Ferrites (magnetic ceramic materials), steatites, titanates, zircon porcelains, wet process porcelains, rigid coaxial line.	37
General Electric Co., Apparatus Div. Capacitors, transformers (radio) voltage regulators, wire and cable, soldering irons, auxiliary relays manual switches, selenium rectifiers.	113–119
General Electric Co., Electronic Div. Miniature TV equipment, plug-in and portable amplifiers, precision test equipment, loudspeakers, cartridges, single sideband selector, tone arms.	113–119
General Electric Co., Tube Div. Transmitting tubes, industrial tubes, receiving and cathode ray tubes including the 16AP4 metal tube and the 12KP4 "Daylight" tube.	113–119
General Electronics, Inc., Paterson, N. J. Electron tubes, oscillators, rectifier, thyratrons and cathode ray.	72
General Radio Co., Cambridge, Mass. Television monitors, new light meter and Color photography, UHF connectors and measuring circuits, radiation counters, Impedance bridges.	92 & 93
Gibbs Division, George W. Borg Corp., Delavan, Wis. Electronic equipment and components.	236

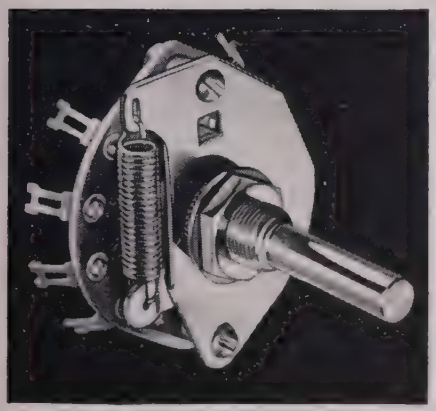
(Continued on page 74A)

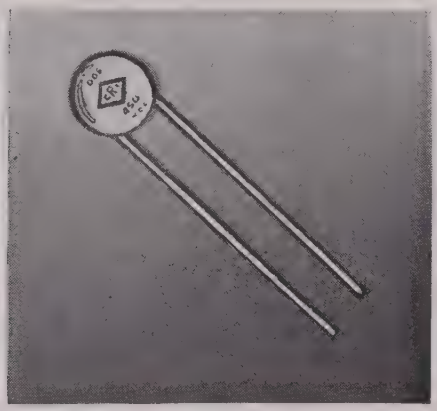
Electronic Industry



4 CRL's *Couplate* consists of a plate lead resistor, grid resistor, plate by pass capacitor and coupling capacitor. Write for Bulletin 42-6.

5 Centralab's development of a revolutionary, new *Slide Switch* promises improved AM and FM performance! Flat, horizontal design saves valuable space, allows short leads, convenient location to coils, reduced lead inductances for increased efficiency in low and high frequencies. Rugged, efficient. Write for Bulletin 953.





6 Great step forward in switching is CRL's new *Rotary Coil and Cam Index Switch.* Its coil spring gives you smoother action, longer life.

7 For by-pass or coupling applications, check CRL's original line of ceramic disc and tubular *Hi-Kaps.* For full facts, order Bulletins 42-3 and 42-4.

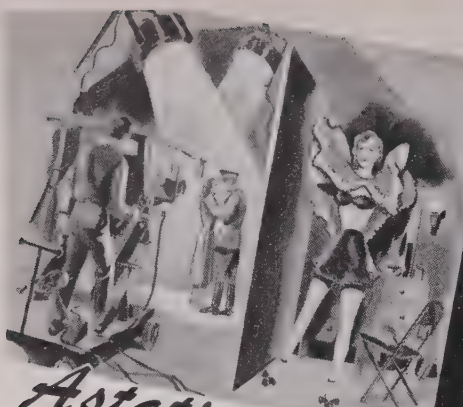
8 Wide range of variations in CRL's Model "M" Radiohm simplifies production and inventory. Bulletin 697-A illustrates convenience, versatility!

LOOK TO CENTRALAB IN 1949! ***First in component research that means lower costs for the electronic industry. If you're planning new equipment, let Centralab's sales and engineering service work with you. Get in touch with Centralab!***

Centralab

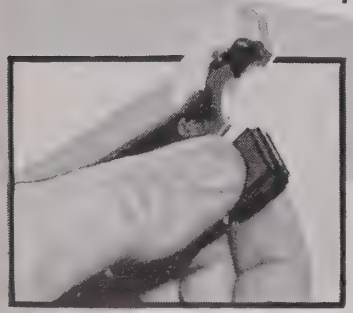
CRL

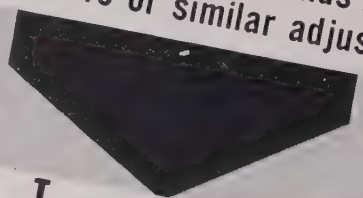
DIVISION OF GLOBE-UNION INC., MILWAUKEE, WIS.



THE QUICKEST CHANGE ON RECORD(S)

Astatic FL SERIES PICKUPS switch from LP Micro-groove to Standard 78 RPM records in seconds . . . with no changing of needle pressure or similar adjustments

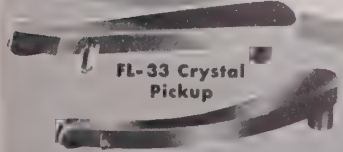




LIKE THE DEMANDS on Television entertainers for speed in changing costumes — there is need for greatest possible ease and speed when phonograph owners change back and forth from 33-1/3 to 78 RPM Records. Public satisfaction and convenience demand it. That's why the two-in-one feature of Astatic's new FL Series Long-Playing Pickups is considered of first importance. Each of these amazing units plays both types of recordings . . . and makes the change-over in seconds. There is no changing of needle pressure, no similar adjustments to make. All that the user need do is change cartridges. Takes only seconds, because the FL Pickups' tiny LP Cartridges fix themselves into playing position on the same slip-in principle which firmly joins barrel and cap of many modern fountain pens.

The reproduction qualities of FL Series Pickups at only five-gram needle pressure are nothing short of spectacular, thanks to complete new engineering, mechanically and electrically. For comparable performance at lower cost, you may want to consider other new Astatic Long-Playing Models. Write for new brochure, giving full details, illustrations.

Astatic Crystal Devices manufactured under Brush Development Co. patents.



FL-33 Crystal Pickup

FLC-33 Crystal Pickup

FLT-33 Crystal Transcription Pickup

The "400" Arm with either QT-33 Crystal Cartridge or MI-2M-33 Magneto Induction Cartridge

THE Astatic CORPORATION
ASTATIC CONNEAUT, OHIO

BALTIMORE

"'Symetron' 50-Kilowatt FM Broadcast Amplifier," by D. L. Balphia, Westinghouse Electric Corporation· November 30, 1948.

BEAUMONT-PORT ARTHUR

"Some Traffic Control Problems and their Solution," by J. D. Southwell, City of Beaumont; September 22, 1948.

"Some Problems of Television," by B. E. Shackelford, 1948 President, The Institute of Radio Engineers; October 2, 1948.

"Construction Details of New KFDM Transmitting Plant," by S. H. Jones, KFDM; November 16, 1948.

"The Stratovision System," by C. E. Nobles Westinghouse Electric Corporation; December 8, 1948.

BUFFALO-NIAGARA

"The Radio Engineers looks at Industrial Electronics," by E. D. Cook, General Electric Company; November 17, 1948.

"Industrial Applications of the Cathode-Ray Oscilloscope," by P. Ebbenhouse, Allen B. Dumont Laboratories, Inc.; December 15, 1948.

CEDAR RAPIDS

"Radio—Radar—Microwaves," by J. O. Perrine, American Telephone and Telegraph Company; November 9, 1948.

CLEVELAND

"Servo-Mechanisms," by W. Buhl, Jack and Heintz Precision Industries; November 16, 1948.

COLUMBUS

"A New Microwave Triode," by J. A. Morton, Bell Telephone Laboratories; November 17, 1948.

"A New Semiconductor Amplifier," by J. A. Morton, Bell Telephone Laboratories; November 17, 1948.

CONNECTICUT VALLEY

"AC and DC Electronic Voltage Regulators," by L. Helterline, Sorenson and Company, Inc.; November 18, 1948.

"The Handling of Ideas Submitted to the General Electric Patent Department," by M. W. Morse, General Electric Company; December 16, 1948.

DALLAS-FORT WORTH

"Technical Considerations in Television Receivers," by J. E. Palmer, West Texas Appliance Company; November 10, 1948.

DAYTON

"Phase Distortion In Audio Systems," by L. A. DeRosa, Federal Telecommunications Laboratories, Inc.; December 9, 1948.

DES MOINES

"The Electron Microscope," by P. H. Carr, Iowa State College; November 17, 1948.

EMPORIUM

"Modern Quality Control," by S. Collier, Johns Manville Corporation; December 7, 1948.

Election of Officers; December 7, 1948.

HOUSTON

"Ultrasonics—Industrial Applications," by J. Woodburn, Rice Institute; October 15, 1948.

"Stratovision," by C. E. Nobles, Westinghouse Electric Corporation; December 7, 1948.

LOS ANGELES

"The Transistor," by J. A. Bardeen and W. Shockley, Bell Telephone Laboratories; November 18, 1948.

(Continued on page 39A)

SECTION MEETINGS

(Continued from page 36A)

LOUISVILLE

"Application of Induction Heating in the Manufacture of Tractors," by J. Graham, International Harvester Company; November 12, 1948.

"The Design and Manufacturing of Phasing Equipment for Directional Antenna," by J. S. Brown, Andrews Corporation; December 10, 1948.

MILWAUKEE

"Common Misconceptions in the Engineering Field," by W. E. Richter, Allis-Chalmers Manufacturing Company; November 10, 1948.

"X-Ray Sources for Roentgen Therapy," by D. Trout, General Electric X-Ray Corporation; November 17, 1948.

"Roentgen Irradiation of Tumors," by M. Friedman, New York University; November 17, 1948.

"Sound and Video Separation Circuits," by B. Parmet, Motorola Corporation; December 8, 1948.

NEW MEXICO

"Some Topics in FM Theory and Application," by C. W. Carnahan, Sandia Laboratory; November 19, 1948.

"Measurements at Ultra-High Frequencies," by W. R. Hewlett, Hewlett-Packard Company; December 17, 1948.

NEW YORK

"Magnetic Materials with a Rectangular Hysteresis Loop," by E. Both, Fort Monmouth Signal Corps Engineering Laboratories; October 20, 1948.

"Fundamental Operation and Application of Magnetic Amplifiers," by R. E. Morgan, General Electric Company; October 20, 1948.

"The Transistor—A Crystal Triode," by W. Shockley and J. A. Becker, Bell Telephone Laboratories; November 10, 1948.

OTTAWA

"Pulse Time Modulation," by A. R. St. Louis, Federal Electric Manufacturing Company; October 28, 1948.

"Television," by H. S. Dawson, Canadian General Electric Company; November 18, 1948.

"GM Counters and their Applications," by E. Lever, Electronic Associates Ltd.; December 9, 1948.

PHILADELPHIA

"Recent Advances in the Theory of Communications," by C. E. Shannon, Bell Telephone Laboratories; December 2, 1948.

PITTSBURGH

"Particle Accelerators and Accelerated Particles," by E. Creutz, Carnegie Institute of Technology" November 8, 1948.

PORTLAND

"The Transistor, its Characteristics and Properties," by W. H. Brattain, The Bell Telephone Laboratories; November 18, 1948.

"Some Design Problems of a High-Gain, Wide-Band Direct-Coupled Oscilloscope," by L. Belleville, Tektronix Inc.; November 22, 1948.

PRINCETON

"Microwave Radio Relay Systems," by J. W. McRae, Bell Telephone Laboratories, December 2, 1948.

ROCHESTER

"Teleran—Air Navigation and Traffic Control through Pictorial Display," by D. Ewing, Radio Corporation of America, December 2, 1948.

(Continued on page 40A)

Speaking of Percentages

THE

MYCALEX

CORPORATION OF AMERICA

sincerely believes that every user of insulation will be interested in the following progress report on Mycalex 410, molded—exclusive formulation of the Mycalex Corp. of America—for the four year period, 1945-1948:

- Average selling price of Mycalex 410 *reduced* by more than 50% over the past four year period.
- Raw material costs *increased* approximately 150%.
- Labor costs to make Mycalex 410 *increased* approximately 50%.
- Demand and production of Mycalex 410 *increased* approximately 500%.

The constantly increasing number of users of Mycalex 410 have benefited—with a better product—better service and deliveries—at a *lower cost.*

Research, plant expansion, improved engineering, additional new efficient manufacturing equipment—have permitted us to make available in increased quantities——Mycalex 410—molded—at prices comparable to other less efficient molded insulations.

MYCALEX 410 is now priced to meet rigid economy requirements

Send us your blue prints. We can handle the tough jobs as well as the less complicated ones. Any interest evidenced on your part in Mycalex products and services—will receive the prompt, courteous and intelligent attention of a competent Mycalex factory sales engineer. He will receive the fullest backing and cooperation from other factory executives—to serve you promptly—with a quality product and at an economical and fair price.

SINCE 1919 MYCALEX THE INSULATOR

AIRCRAFT
RADIO
CORPORATION

Announces

THE TYPE H-12

SIGNAL GENERATOR

900-2100 Megacycles

. . . for research and for production testing

- 900-2100 megacycles, single band
- Continuous coverage with single-dial control directly calibrated
- Directly calibrated attenuator, 0 to -120 dbm
- CW or AM pulse modulation
- Extensive pulse circuitry

Write for details

Aircraft Radio Corporation
BOONTON, New Jersey

ARC

Dependable Electronic Equipment Since 1928

SECTION MEETINGS

(Continued from page 39A)

SACRAMENTO

"Electrical and Mechanical Measurements Using Electronic Instruments," by N. Porter, Hewlett-Packard Company; November 17, 1948.

"X-Ray Sources for Industrial and Therapy Applications," by E. D. Trout, General Electric Company; December 13, 1948.

"Medical Applications of X-Ray and Demonstration of New Million Volt X-Ray Unit Recently Installed at Sutter Hospital," by C. E. Grayson, Sutter Hospital; December 13, 1948.

SAN DIEGO

"The Transcontinental Coaxial Cable System," by C. T. Koerner, Pacific Telephone and Telegraph Company; November 10, 1948.

SAN FRANCISCO

"Microwaves in Molecular Spectroscopy," by W. Gwinn, University of California; November 10, 1948.

"Status of Television in the Bay Area," by R. A. Isberg, KRON-TV, H. N. Jacobs, KGO-TV, and A. F. Towne, KPIX-KSFO; December 8, 1948.

SEATTLE

"The Transistor," by W. Brattain, Bell Telephone Laboratories; November 12, 1948.

Election of Officers; December 14, 1948.

SYRACUSE

"Microwave Astronomy," by C. H. Burrows, Cornell University; November 12, 1948.

"Indoor and Outdoor Experiments in Rain and Snow," by V. J. Shaefer, General Electric Company; November 29, 1948.

TOLEDO

"Film Projection for Television," by L. C. Downes, General Electric Company; November 22, 1948.

TORONTO

"Modern Electronic Instrument Techniques," by R. Cox, National Research Council Atomic Energy Project; November 15, 1948.

"Techniques of Television Sound," by H. H. Tanner, Northern Electric Company; December 6, 1948.

TWIN CITIES

"Electronic Properties of Semiconductors and the Transistor," by W. H. Brattain, Bell Telephone Laboratories; November 29, 1948.

WASHINGTON

"The Electron Wave Tube—A Novel Method of Amplification and Generation of Microwave Energy," by A. V. Haeff, Naval Research Laboratory; December 13, 1948.

Election of Officers; December 13, 1948.

SUBSECTIONS

HAMILTON

"Twin 50-Kw B.C. Transmitters CBL-CJBC," by J. C. R. Punchard, Northern Electric Company; November 29, 1948.

LANCASTER

"High Resolution Nuclear Particle Counting Circuits," by F. W. Van Name, Jr., Franklin and Marshall College; November 10, 1948.

LONG ISLAND

"The Complex Frequency Plane as a Tool for the Engineer," by W. H. Huggins, Air Materiel Command; November 17, 1948.

(Continued on page 42A)

Finest Cored Solder in the World

ERSIN Multicore

The only 3 core solder made with ERSIN FLUX...the original non-corrosive, extra-active flux

TECHNICAL ADVANTAGES

Multicore Solder

- Three separate cores of flux eliminate possibility of no flux in a portion of the wire, which may occur in single cored solder. Guaranteed continuity of the flux stream prevents "dry" joints, i.e. those having high electrical resistance.
- Although there are three cores of flux in Multicore, the total percentage of flux to solder is no greater than in single cored solder.
- Very rapid melting results from the multiple core construction which provides thinner walls of solder than are found in same gauge single cored solder.
- Multicore's unique properties make perfect joints possible on difficult metals and alloys, even if oxidized.
- Ability to tin rapidly produces perfect joints with less solder. Greater coverage per pound.

Ersin Flux

- Ersin Flux is an exclusive product of Multicore Solders Limited, and is only supplied as part of Multicore Solder. It is a high grade, water white rosin, homogeneously activated.
- Confers on rosin a vigorous fluxing action without affecting the non-corrosive and protected features of the original rosin.
- Soldered joints made with Ersin Flux do not corrode even after prolonged exposure to a degree of humidity.
- Reduces the surface tension of molten solder, causing it to wet metals rapidly, increasing speed of operation with resultant production economies.
- Free from objectionable odor. Non-toxic in use.
- Leaves nothing but pure rosin on the work after soldering, and may be used wherever plain rosin is specified.

ALLOY AND MELTING POINTS OF ERSIN MULTICORE SOLDER

Alloy Tin/Lead	Multicore Color Code	Solidus °C.	Liquidus °C.	Recommended bit temperature °C.	USES
60/40	Red	183°	190°	230°	High quality work requiring low melting point alloy.
50/50	Yellow	183°	212°	252°	Hand soldering. Radio, telephone and electrical equipment; batteries.
45/55	Crimson/Buff	183°	227°	267°	
40/60	Green	183°	238°	278°	
30/70	White	183°	257°	297°	Fuses, motors, dynamos.
20/80	Purple	183°	276°	316°	Lamps, motors, dynamos.

STANDARD GAUGES

Standard Wire Gauge	Diameter in Inches	Diameter in Millimeters	Approximate Number of Feet per lb. ALLOY 60/40	50/50	45/55	40/60	30/70	20/80
10	1.128	3 251	25.2	24.1	23.5	23.0	21.9	20.8
12	0.104	2.642	38.1	36.5	35.2	34.9	33.1	31 5
13	0.092	2.337	48.7	46.6	45.3	44.5	42.3	40.3
14	0.080	2.032	64.4	61.7	59.2	58.6	56.0	53 3
16	0.064	1 626	100.5	96.4	94.3	92.1	87.5	83.3
18	0.048	1.219	178.5	171.0	167.8	163.5	155.5	148.0
19	0.040	1.016	257.5	246.5	240.4	235.5	224.0	213.0
20	0 036	0 914	318.0	304.5	302.5	291.0	276.5	263 0
22	0.028	0 711	526 0	503.0	492.0	481.0	457.0	435 0

ERSIN MULTICORE SOLDER is made in a wide range of gauges, as shown. It can also be supplied in any intermediate size. For general radio and electronic production 13, 14, 16 and 18 S.W.G are the most widely used gauges.

◆

FEDERAL SPECIFICATIONS

ERSIN Multicore Solder meets all requirements of Federal Specification QQ-S-571-b September, 1947 entitled "Solder; Soft Tin Lead" as certified by the New York Testing Laboratory Incorporated.

◆

ALL GAUGES AND ALLOYS READILY AVAILABLE FROM NEW YORK STOCK

Write for Helpful Booklet, "SOLDERS AND SOLDERING"

Address U.S.A. and Canadian inquiries to:

BRITISH INDUSTRIES CORP.

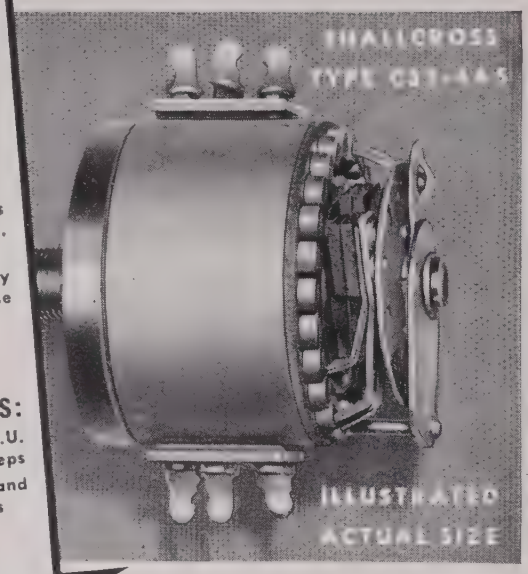
315 Broadway, New York 7, N. Y.

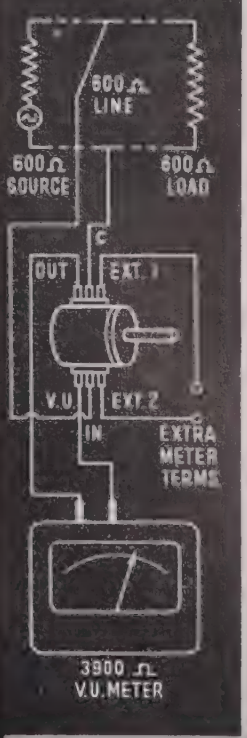
Inquiries regarding other territories to:

MULTICORE SOLDERS LTD.

FEATURES NEVER BEFORE AVAILABLE IN A V.U. METER MULTIPLIER

- FIVE STEP STRAIGHT "T" CIRCUIT
- ONLY 1¾" DIAMETER
- IN ATTENUATOR "OFF" POSITION:
  1. Extra pair of Terminals for separate use of V.U. Meter.
  2. "T" Network completely disconnected from line and meter.
- TWO STANDARD ATTENUATION RANGES:
  1. 0 (1mw) to +16 V.U. and OFF in 4 V.U. steps
  2. +4 to +20 V.U. and OFF in 4 V.U. steps
- CONTACT SPACING: 30° between adjacent steps





The ingenious electrical-mechanical design of these new type C35 V.U. Meter Multiplier Attenuators provides five step Straight T performance in a control size normally limited to ladder and potentiometer circuits.

A pair of extra terminals greatly increases the utility of this unit, since in the OFF position the V.U. Meter Multiplier network is automatically disconnected from the line which it normally bridges, and the V.U. Meter—completely isolating both.

As illustrated in the circuit at the left, the V.U. Meter is connected to the auxiliary pair of terminals on the Multiplier when in the OFF position, thus enabling the meter to be used for volume indication on another line, for tube checking and other purposes. Use of additional V.U. Meter Multipliers permits a single meter to be used for any number of lines with each line isolated from all others. The size and technical features of this new unit suit it ideally for use in consolettes.

Prices and delivery of this unit as described or as modified to meet your requirements available on request. Address: Dept. PR-29, Shallcross Manufacturing Company, Collingdale, Pa.

Shallcross

SECTION MEETINGS

(Continued from page 40A)

MONMOUTH

"Magnetic Materials with a Rectangular Hysteresis Loop," by E. Both, Signal Corps Engineering Laboratories; September 15, 1948.

"Fundamental Operation and Application of Magnetic Amplifiers," by R. E. Morgan, General Engineering and Consulting Laboratory; September 15, 1948.

"Low Noise IF Input Circuit," by R. T. Adams, Federal Telecommunications Laboratories; October 20, 1948.

"The Transistor," by J. W. McRae, Bell Telephone Laboratories; November 18, 1948.

NORTHERN NEW JERSEY

"Analysis and Performance of Waveguide Hybrid Rings for Microwave," by H. T. Budenbom, Bell Telephone Laboratories; October 20, 1948.

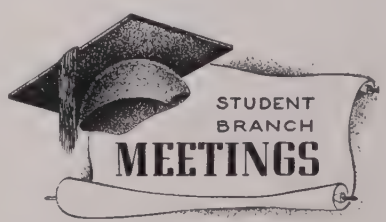
"A Signal Generator for 900–2100 Mc," by G. P. McCouch, Aircraft Radio Corporation; October 20, 1948.

"A Signal Generator for 23,500–24,500 Mc," by P. B. King, Aircraft Radio Corporation; October 20, 1948.

"A Medium-Powered Travelling Wave Amplifier for Microwave," by G. C. Dewey, Federal Telecommunications Laboratories; November 17, 1948.

"The Surge Testing of High Vacuum Tubes," by H. J. Dailey, Westinghouse Electric Corporation; December 8, 1948.

"Application of Radar Techniques to a System for High-Speed X-Ray Movies," by D. C. Dickson, Jr., C. T. Zavales and L. F. Ehrke, Westinghouse Electric Corporation; December 8, 1948.



ALABAMA POLYTECHNIC INSTITUTE—IRE BRANCH

"Audio Equipment," by D. K. Briggs, Western Electric Company; December 6, 1948.

UNIVERSITY OF ALBERTA—IRE BRANCH

"Ice Conditions on the Bow River and Iceberg Carrier of World War II," by L. H. Nichols, University of Alberta; November 2, 1948.

"Physics in 1947," by D. B. Scott, University of Alberta; November 23, 1948.

UNIVERSITY OF ARKANSAS—IRE BRANCH

"The Aims of the IRE," by C. E. Cook, Student, University of Arkansas; September 23, 1948.

"The RCA Dynamic Demonstrator," by V. Papoulias, Student, University of Arkansas; October 6, 1948.

CALIFORNIA INSTITUTE OF TECHNOLOGY—IRE

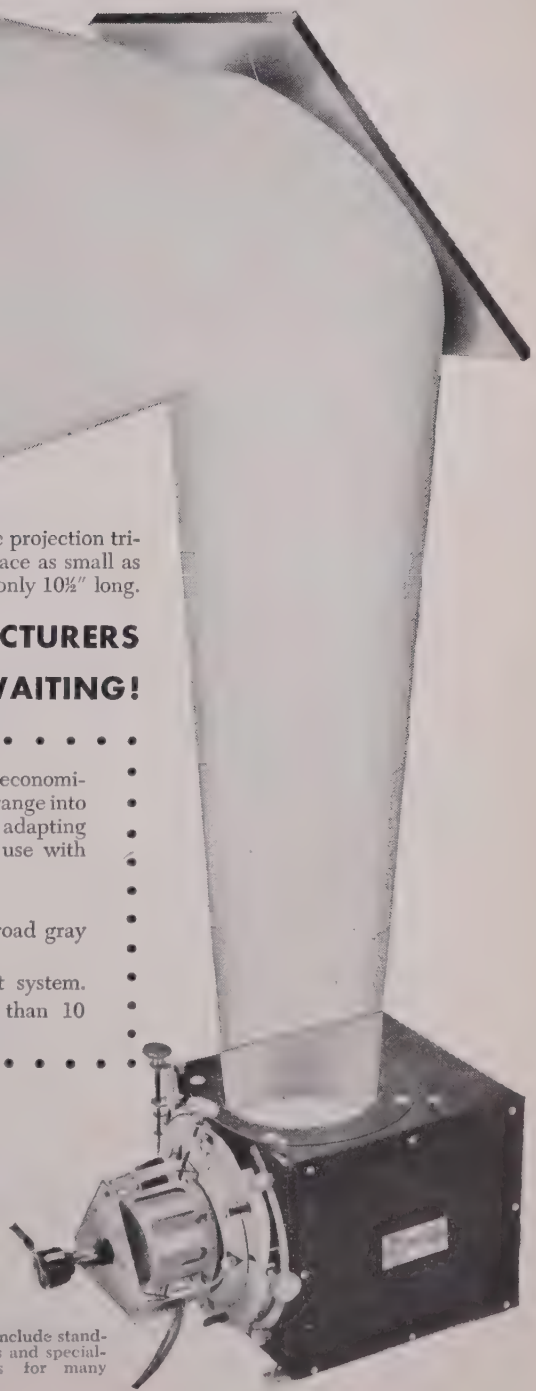
"Telemetering of Guided Missiles," by F. Lehan, Jet Propulsion Laboratory; December 6, 1948.

COLUMBIA UNIVERSITY—IRE-AIEE BRANCH

"The Mathematical Representation of Human Responses," by J. R. Ragazzini and L. J. O'Neill, Columbia University; October 29, 1948.

(Continued on page 44A)

PROTELGRAM FOR PERFECTED LARGE SIZE HOME TV PROJECTION



The 2½" magnetic projection triode 3NP4 has a face as small as a compact and is only 10½" long.

HERE'S THE OPPORTUNITY THAT MANUFACTURERS OF TELEVISION RECEIVERS HAVE BEEN AWAITING!

10 SIGNIFICANT FEATURES

1. Flat 16" x 12" non-reflecting picture provides fatigueless viewing from less than 5 feet and upward!
2. Wide-angle visibility — *square corners.*
3. True photographic black and white picture quality—no discoloration.
4. Compact unit—suitable for table model cabinets.
5. Long-life, low-cost picture tube.
6. Manufacturers can most economically extend their product range into projection television by adapting their 10" EM chassis for use with PROTELGRAM.
7. Easy to service.
8. High contrast ratio and broad gray tone range.
9. Simple optical adjustment system.
10. *Quality built* after more than 10 years of development.

NORELCO PROTELGRAM consists of a projection tube, an optical box with focus and deflection coils, and a 25 kv regulated high-voltage supply unit, making possible large-size home projection. More than ten years of exhaustive research resulted in this ideal system for reproducing a projected picture. The optical components are designed to produce perfected projection for a 16" x 12" image, the optimum picture size for steady, distant observation and also for *proper viewing at less than 5 feet.*

Other NORELCO products include standard 10" direct-viewing tubes and special-purpose cathode-ray tubes for many applications.

NORTH AMERICAN PHILIPS COMPANY, INC. Norelco

PROTELGRAM IS PICTURE PERFECTION IN PROJECTION

NORTH AMERICAN PHILIPS COMPANY, INC.

DEPT. TP-2, 100 EAST 42nd STREET, NEW YORK 17, N. Y.

IN CANADA: PHILIPS INDUSTRIES LTD., 1203 PHILIPS SQUARE, MONTREAL ★ EXPORT REPRESENTATIVE: PHILIPS EXPORT CORPORATION, 100 EAST 42ND STREET, NEW YORK 17, N. Y.

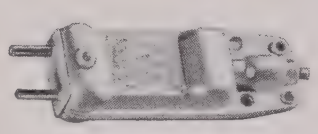
WEBSTER ELECTRIC

THE Featheride LINE IS COMPLETE!

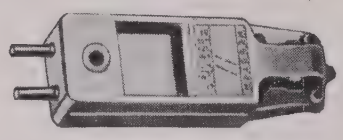
REG. U. S. PAT. OFFICE

Webster Electric provides a complete line of precision-built cartridges and tone arms to meet the most exacting of today's requirements . . . a variety of tracking pressures and net weights . . . a selection of voltage outputs and response characteristics. Choose from the wide range of perfected models available; special requirements will receive detailed consideration. Write for complete information.

CRYSTAL CARTRIDGES



Series F . . . Light Weight



Series N . . . General Purpose

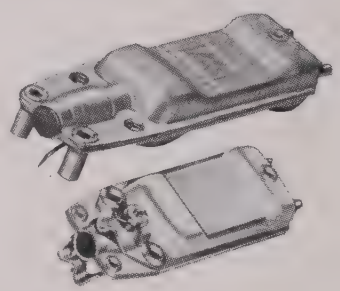
FOR LP RECORDS

Model F 13

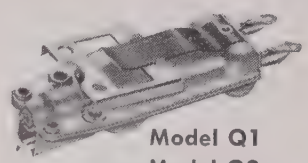
Specially designed to give matchless performance to the new LP records. Comes complete with replaceable osmium-tipped needle and guard.

Model F 14

This model cartridge is for both LP and standard records. A "twist of the wrist" converts it from one to the other, at the listener's pleasure. Complete with needles and guard assembly.



RETRACTABLE CARTRIDGES



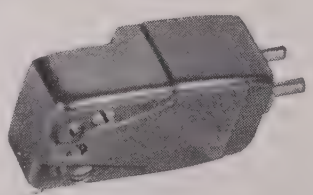
Model Q1
Model Q2

This cartridge protects record, needle and crystal from accidental injury due to rough handling of the tone arm. Exceptionally quiet playing. Available in 1 volt or 2 volt models.

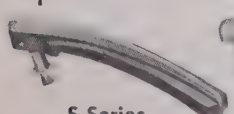
MAGNETIC CARTRIDGES

Model M1

This new magnetic cartridge incorporates the latest refinements for superior playing performance. Provides .1 volt output at 1000 cps . . . comes complete with osmium-tipped replaceable needle.



FEATHERIDE TONE ARMS

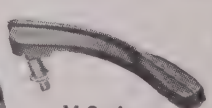


S Series

A new die-cast zinc alloy tone arm for use with F series cartridge, tracking at very low pressure.

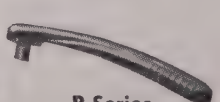
T Series

Lightweight, low-inertia feature. This tone arm stamped of aluminum. Designed for use with N Series cartridges.



V Series

Beautiful styling . . . exceptionally rigid, supplied with high fidelity cartridges, retractable cartridge, and M1 magnetic cartridge.



P Series for LP Records

This tone arm tracks at only 7 grams, providing .8 volts output at 1000 cps. Supplied with F13 cartridge.

(Licensed under patents of the Brush Development Company)

WEBSTER ELECTRIC

RACINE WISCONSIN

Established 1909

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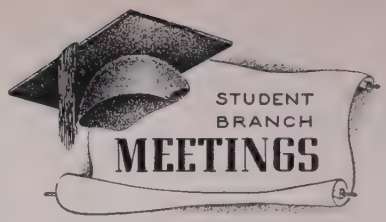


(Continued from page 42A)

UNIVERSITY OF FLORIDA—IRE-AIEE BRANCH

"The Electric Eel," by J. Payne, Student, University of Florida; November 11, 1948.

"An Electronic Vapor Detector," by H. S Nielsen, Student, University of Florida; November 11, 1948.

"Rain and Radar in Ohio," by H. A. Owen, University of Florida; December 2, 1948.

IOWA STATE COLLEGE—IRE-AIEE BRANCH

"New Horizons in Communications," by J. O. Perrine, American Telephone and Telegraph Company; November 3, 1948.

"Horizons in Illuminations," by H. L. Logan, Holophane Company; November 17, 1948.

"Digital Computers," by J. V. Atenasoff, Bureau of Naval Ordnance; December 2, 1948.

"Photography and Science," (film) by A. H. Hausrath, Office of Naval Research; December 2, 1948.

STATE UNIVERSITY OF IOWA—IRE BRANCH

"Professional Engineering," by C. Stanley, Stanley Engineering Company; October 27, 1948.

" A New Horizon in Communications," by J. O. Perrine, American Telephone and Telegraph Company; November 8, 1948.

"Status of the IRE and Status of Television," by T. Hunter, Hunter Manufacturing Company; December 1, 1948.

"Use of the Cathode-Ray Oscilloscope by Unskilled Labor," by H. Talmadge, Student, State University of Iowa; December 8, 1948.

"Industrial Applications of the Photoelectric Cell," by Mr. Wilkinson, Student, State University of Iowa; December 8, 1948.

"Cadmium-Nickel Batteries," by J. E. King, Student, State University of Iowa; December 8, 1948.

"Miller Effect on Frequency Modulation," by M. B. Jones, Student, State University of Iowa; December 8, 1948.

"What the Patent Office Means to the Engineer," by D. McMannis, Student, State University of Iowa; December 8, 1949.

KANSAS STATE COLLEGE—IRE-AIEE BRANCH

"Recent Developments in Vacuum Tubes," by W. James, Radio Corporation of America; October 28, 1948.

"The Magnetron and its Applications," by H. Stout, Midwest Research Institute; November 18, 1948.

MICHIGAN STATE COLLEGE—IRE-AIEE BRANCH

"Applications of Electronics in Industry," by G. Chute, General Electric Company; November 17, 1948.

UNIVERSITY OF MINNESOTA—IRE-AIEE BRANCH

"AC Distribution Problems in the Twin Cities Area," by E. Ewold, Northern States Power Company; October 19, 1948.

NEWARK COLLEGE OF ENGINEERING—IRE-AIEE BRANCH

"Television Receivers," by I. D. Olin, Student, Newark College of Engineering; December 3, 1948.

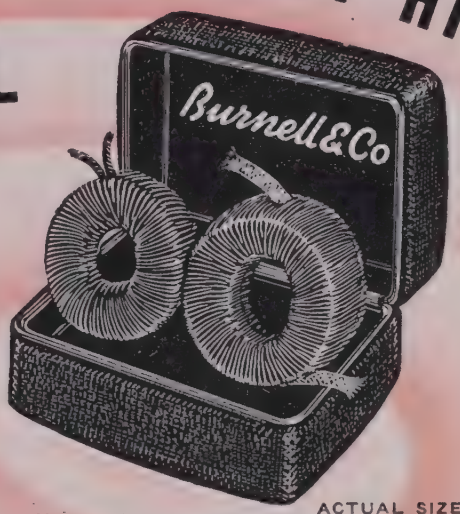
"Television Receivers," Part II, by I. D. Olin, Student, Newark College of Engineering; December 17, 1948.

THE COLLEGE OF THE CITY OF NEW YORK—IRE BRANCH

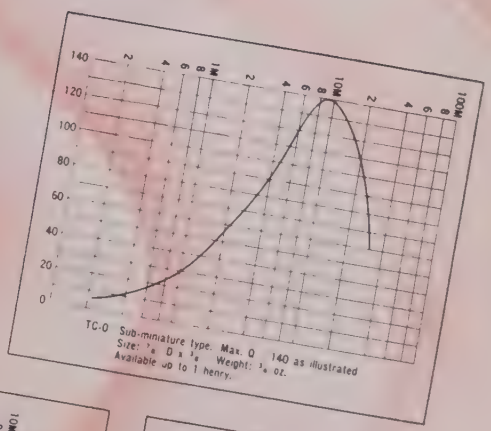
"Nuclear Accelerators," by S. Schneider, Student, College of the City of New York; October 26, 1948.

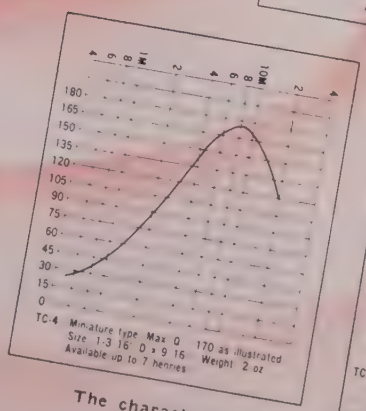
(Continued on page 46A)

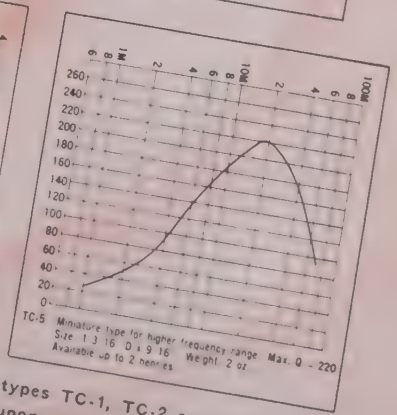
BURNELL & CO., A LEADER IN THE DEVELOPMENT OF MINIATURE AND SUB-MINIATURE COILS AND FILTERS.. INTRODUCES.. THE 'WEDDING RINGS', WORLD'S SMALLEST HIGH 'Q' TOROIDAL COILS



ACTUAL SIZE







The characteristics of the types TC-1, TC-2 and TC-3 are available upon request.

Since discovering that toroidal coils are the solution to problems in compactness of communication and control equipment, design engineers have been confronted with the ever pressing problem of miniaturization.

A major step towards a solution has now been found and we take pleasure in presenting to the electronics field, the penultimate in the design of miniature high Q coils, the types TC-4 and TC-5 and the ultimate, sub-miniature TC-0 which is not much larger than a thumb nail.

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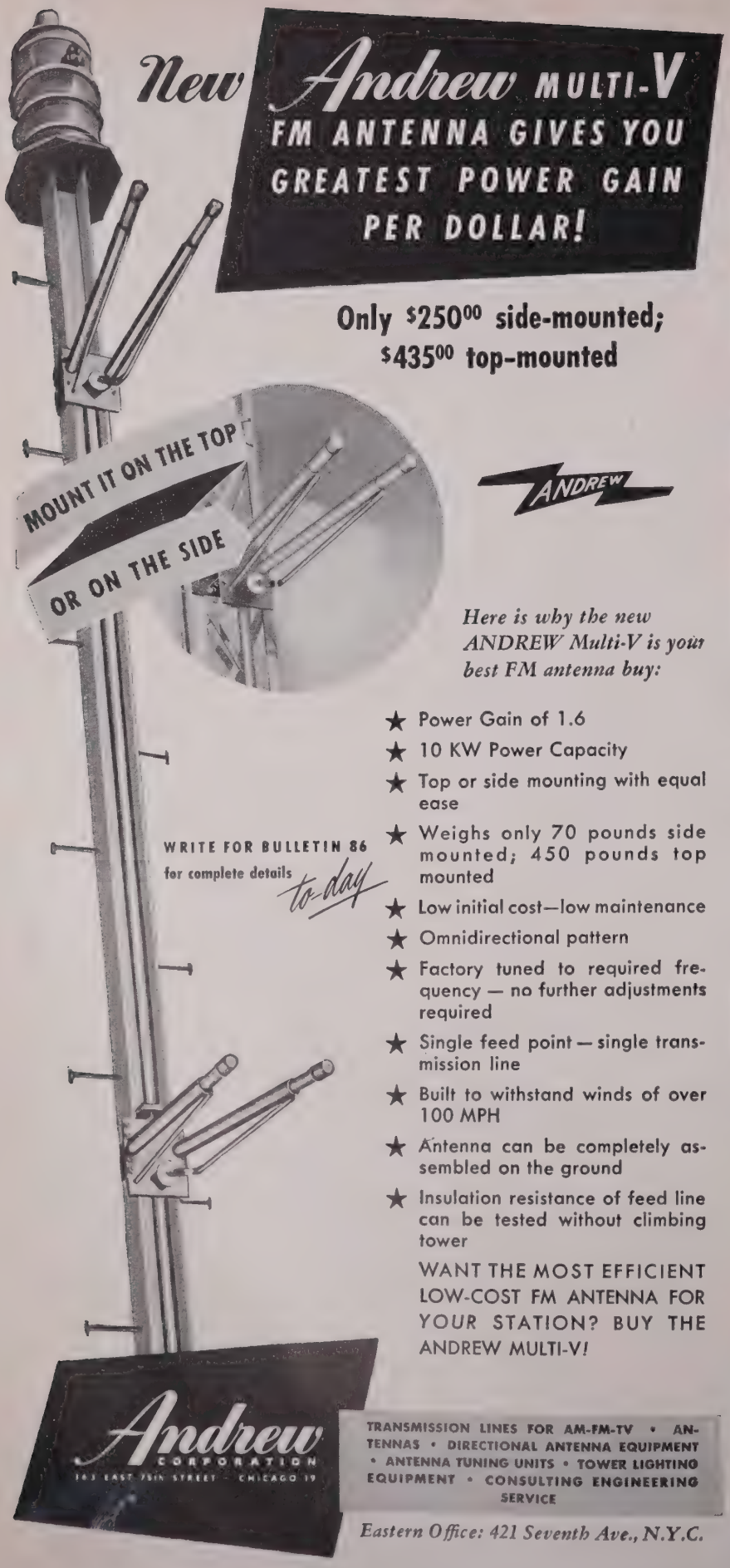
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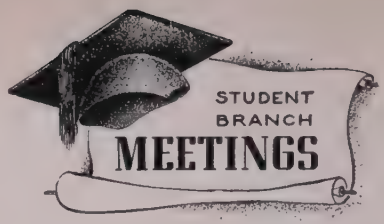

(Continued from page 44A)

"Magnetic Tape Recording for the Home," by N. M. Haynes, Amplifier Corporation of America; November 16, 1948.

"Intermodulation Measuring Equipment," by C. R. Keith, Western Electric Company; November 30, 1948.

NEW YORK UNIVERSITY—IRE BRANCH

"The Geiger Counter and its Applications," by M. Youdin, Amperex Corporation of America; November 9, 1948.

"An Electron Tube for Viewing Magnetic Fields," by S. G. Lutz, New York University; December 3, 1948.

NORTH CAROLINA STATE COLLEGE—IRE BRANCH

"Ionospheric Wave Propagation," by A. G. McNish, National Bureau of Standards; October 27, 1948.

"Radio Receivers, Panadapters, Wire and Tape Recorders," by S. H. Kahn, Southeastern Radio Company; November 10, 1948.

"Recent Developments in FM Broadcasting," by J. D. Bivens, Radio Engineering Laboratories, Inc., December 8, 1948.

UNIVERSITY OF NORTH DAKOTA—IRE-AIEE BRANCH

"The Role Lignite Can Play in the Development of the E.E.," by A. C. Burr, United States Bureau of Mines; December 8, 1948.

NORTHWESTERN UNIVERSITY—IRE-AIEE BRANCH

"Scientific Research in the Field of Neuropsychiatry," by W. D. McCulloch, University of Illinois; November 16, 1948.

UNIVERSITY OF NOTRE DAME—IRE-AIEE BRANCH

"The Heat Pump," by E. A. Ambrose, American Gas and Electric Service Corporation; November 16, 1948.

"The Scope of the Engineering Problem," by G. E. Messer, General Electric Company; December 9, 1948.

"Television Program," by E. L. Clark, Radio Corporation of America; December 14, 1948.

OREGON STATE COLLEGE—IRE BRANCH

"Some Design Problems of a High Gain, Wide-Band, Direct-Coupled Oscilloscope," by L. Belleville, Tektronix Laboratories; November 22, 1948.

"Intertoll Dialing," by H. Beckendorf, Pacific Telephone and Telegraph Company; November 30, 1948.

PRATT INSTITUTE—IRE BRANCH

"Facsimile Transmission," by K. Woloschok Associated Press; November 18, 1948.

"Cold Cathode Tubes and Applications," by W. Holden, Bell Telephone Laboratories, Inc.; December 16, 1948.

PURDUE UNIVERSITY—IRE BRANCH

"Popular Misconceptions of Electrical Engineering Principles," by W. Richter, Allis Chalmers Manufacturing Company; December 1, 1948.

RUTGERS UNIVERSITY—IRE-AIEE BRANCH

"Research at Rutgers University," by Dr. Dunnington, Rutgers University; October 12, 1948.

UNIVERSITY OF TEXAS—IRE-AIEE BRANCH

"A Glimpse of the Industrial Future—Now 45,000 Kw are Generated Completely Out-of-Doors," by C. W. Geue, Texas Electric Company; November 1, 1948.

"Distributing the Power," by O. S. Hockaday, Texas Electric Company; November 1, 1948.

(Continued on page 48A)

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1899 50th Anniversary 1949

"Resin-Five" Is More Active . . . More Efficient . . . More Stable . . . Than ANY Rosin Flux . . . And Yet

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Send for Kester's new 28-page manual, "SOLDER and Soldering Technique" . . . a complete analysis of the application and properties of soft solder alloys and soldering fluxes.

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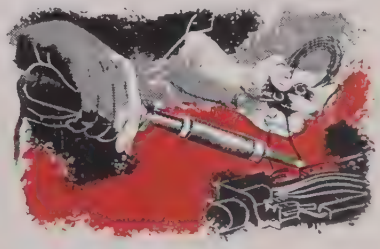
. . . "RESIN-FIVE" is so mobile it is *highly effective in sweating seams.* The activity and stability of "RESIN-FIVE" Flux make this an accomplished fact!



"Resin-Five Is Available In 5 Core Sizes with Varying Percentages of Flux Content. Diameters ranging from .010" to .250"—All Practical Alloys!

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. . . Just Think Of This—"RESIN-FIVE" will solder easily and readily such metals as Zinc, Brass, Nickel Silver, Nickel-Plate, Copper and Ferrous Alloys. REMEMBER "RESIN-FIVE" IS NOT CORROSIVE AND IS NOT CONDUCTIVE!

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. . . "RESIN-FIVE" is *STABLE* under the most extreme soldering temperatures and the Flux still does the job!

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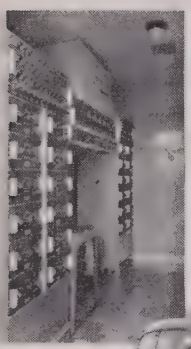
They Discover Oil with Aid of ADC Transformers

THE STORY OF



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SEISMIC EQUIPMENT and OIL PROSPECTING

The Century Geophysical Corporation of Tulsa, Okla., is a prominent manufacturer of seismic equipment for oil prospecting.

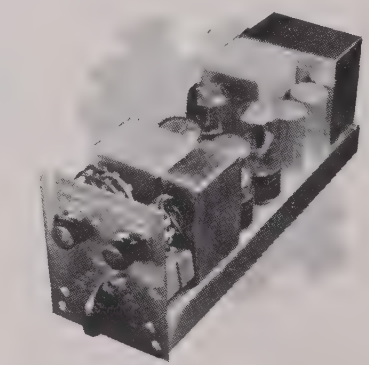
With Century equipment Geophysicists and Geologists determine the general location of new oil fields by charting fault patterns, salt domes, and deep seated limestone beds, all of which is done on a principle of echo.

These techniques require extreme accuracy so that comparison of soundings will reveal slight contour changes at depths of up to three miles.

That **ADC** was selected by Century to manufacture transformers and inductors for their special electronic components is another evidence that ***"Audio Develops the Finest."***

HOW ADC TRANSFORMERS HELP DISCOVER OIL...

Heart of the geophysical unit for detecting oil deposits is the seismic equipment in the recording truck. Century called on **ADC** to work out the complicated specifications on transformers and inductors for seismograph amplifier, etc., to obtain the extreme accuracy, durability and dependability they require.



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Audio Develops the Finest
2855 13th AVE. SOUTH · MINNEAPOLIS 7, MINN.

Student Branch

(Continued from page 46A)

"Engineering Research," by A. W. Straiton University of Texas; November 15, 1948.

UTAH STATE AGRICULTURAL COLLEGE—IRE BRANCH

"Properties of Dielectrics at Ultra-High Frequencies," by W. L. Emery, Utah University; October 27, 1948.

"Practical Television and Programming Problems," by J. Baldwin, Station KDYL; December 1, 1948.

UNIVERSITY OF VIRGINIA—IRE-AIEE BRANCH

"Two-Meter Transceiver Operation," by R. F. Stone, Student, University of Virginia; December 14, 1948.

WAYNE UNIVERSITY—IRE-AIEE BRANCH

"The Organization and Functioning of an FM Station," by W. Fahringer, Station WJR; November 4, 1948.

WORCESTER POLYTECHNIC INSTITUTE—IRE-AIEE BRANCH

"The Dynamic Noise Suppressor Amplifier," by H. H. Scott, H. H. Scott Company; October 23, 1948.

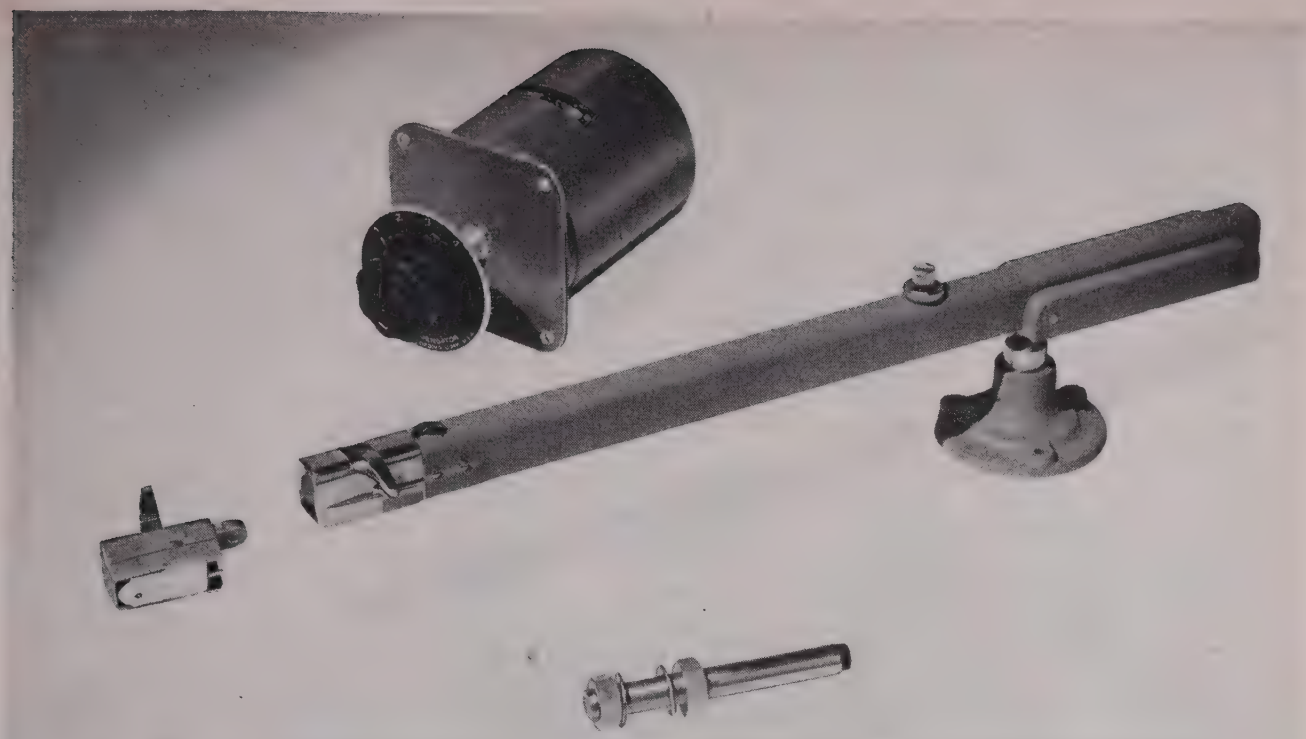
"Engineering Experiences in the Orient," by W. Leavitt, Worcester County Electric Company; November 23, 1948.

The following transfers and admissions were approved and will be effective as of February 1, 1949:

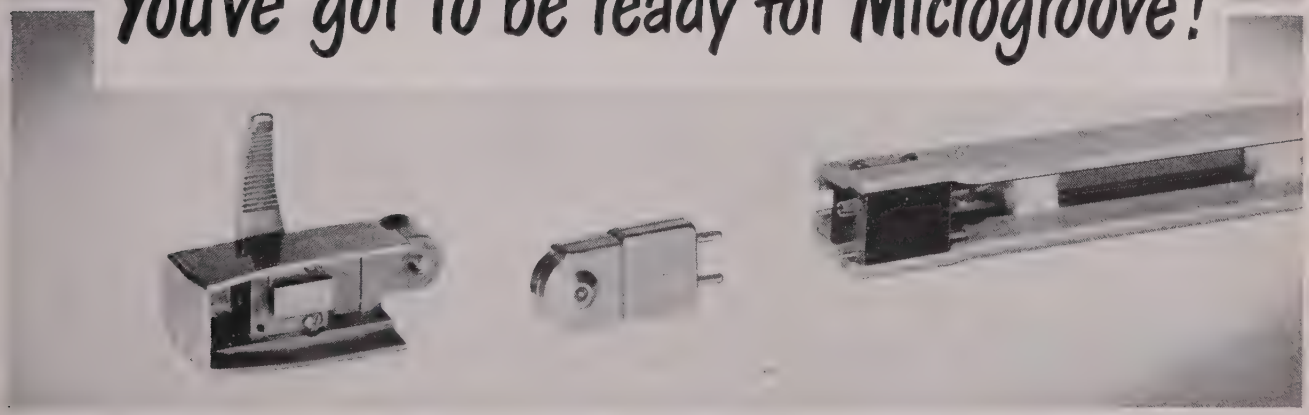
Transfer to Senior Member

Anderson, R. S., 392 Colebourne Rd., Rochester 9, N. Y.
Auerbacher, W. F., 444 E. 21 St., Brooklyn 26, N. Y.
Avins, J., 30 Daniel Low Ter., Staten Island 1, N. Y.
Barlow, D. S., Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.
Battison, J. H., B52 Hudson View Gardens, Pinehurst Ave. & 183 St., New York 33, N. Y.
Borgeson, C. A., 82 Garden Rd., Red Bank, N. J.
Brown, J. S., 1658 W. 101 Pl., Chicago 43, Ill.
Bruene, W. B., 1239 First Ave., S.E., Cedar Rapids, Iowa
Chittick, K. A., 518 Maple Ave., Haddonfield, N. J.
Collins, A. A., Collins Radio Company, Cedar Rapids, Iowa
Creamer, W. J., 331 Center St., Bangor, Me.
Dolnick, A. L., Sylvania Electric Products, 40-22 Lawrence St., Flushing, L. I., N. Y.
Glaser, M., 226-07—137 Ave., Laurelton 13, L. I., N. Y.
Green, J. W., Jr., Professor of Electricity, Unitnt States Military Academy, West Poied, N. Y.
Jacobson, R. I., 120 Bennett Ave., New York 33, N. Y.
Kidd, W. E., 585 Turner Ave., Glen Ellyn, Ill.
Kozanowski, H. N., 435 Washington Ter., Audubon, N. J.
Mair, A. D., c/o Arabian American Oil Company, Dhahran, Saudi Arabia
Manley, J. M., Bell Telephone Laboratories, Murray Hill, N. J.
MacKenzie, A. A., 245 Poplar Ave., Hackensack, N. J.
Morrison, W. C., Random Rd., R.D. 1, Princeton, N. J.

(Continued on page 62A)



You've got to be ready for Microgroove!



MICROGROOVE long-playing recordings are here to stay. This means that every broadcast station and recording studio must have quality equipment, especially for microgroove reproduction.

The new PRESTO type 153 reproducers include two separate Pickering diamond stylus heads for microgroove or regular recording, an exceptionally fine arm, and a 4-position compensating network.

Durability of equipment, fine performance, and economical first cost make these PRESTO reproducers ideal for microgroove and also for lateral standard recordings.

Write today for full specifications on the PRESTO 153M for microgroove recordings and 153R for regular recordings. Your nearest PRESTO distributor can show you the equipment.

FOR HIGHEST FIDELITY . . . IT'S PRESTO DISCS

Microgroove, even more than regular recording, demands a perfect disc. The answer is Presto. For, sixteen years ago, Presto made the *first* lacquer-coated discs . . . and today Presto discs are *first* in quality.

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WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT AND DISCS

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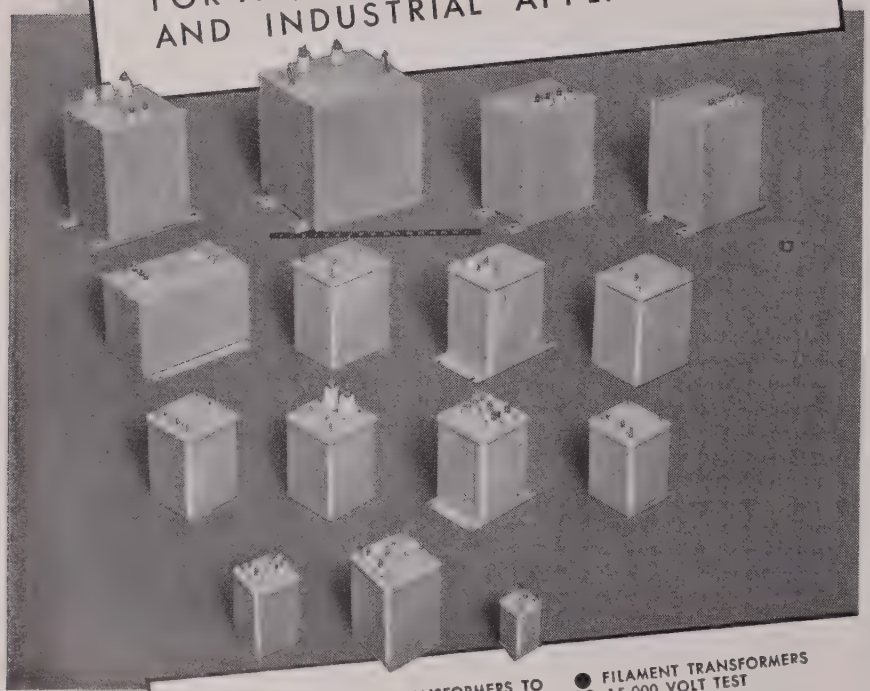
FOR AM, FM AND TV—LABORATORY AND INDUSTRIAL APPLICATIONS



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- FILTER REACTORS
- FILAMENT TRANSFORMERS TO 15,000 VOLT TEST
- PLATE FILAMENT TRANSFORMERS LOW VOLTAGE

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- UNIFORM STREAMLINED APPEARANCE
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Here is one of the finest and most complete lines of standard transmitter components available today. Built to the same well-known high standards as N·Y·T custom-built units, they bring to the design engineer the full economy of standardized construction. Superbly constructed, inside and out, each unit fully reflects the years of experience that have made the name NEW YORK TRANSFORMER synonymous with quality, integrity and dependability wherever inductive components are used.

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ALPHA, NEW JERSEY

MEMBERSHIP

(Continued from page 48A)

Ogilvie, A. R., 51 Michael Lane, Millbrae, Calif.
Rennick, J. L., 2008 N. 74 Ave., Chicago 35, Ill.
Rich, G. C., 317 Park Ave., Manhasset, L. I., N. Y.
Roe, J. H., 315 Newten Ave., Collingswood, N. J.
Sloughter, G. S., R.D. 4, Ridgefield, Conn.
Sternke, E. C., 311 Robert Ave., Oxnard, Calif.
Strom, C. A., Jr., 1910 Oak Dr., West Belmar, N. J.
Ware, W. H., Institute for Advanced Study, Princeton, N. J.
Williams, A. J., Jr., 4901 Stenton Ave., Philadelphia, Pa.
Wilton, R., 71 Carling St., London, Ont., Canada

Admission to Senior Member

Augustadt, H. W., 903 Boulevard, Westfield, N. J.
Bright, D. C., 3629 Stratmore Ave., Youngstown 7, Ohio
Busenkell, C. C., 11600 Sherman Way, N. Hollywood, Calif.
Calvert, J. F., Department of Electrical Engineering, Northwestern University, Evanston, Ill.
Conrad, A. G., Yale Station, New Haven, Conn.
Denton, B. E., Kings Highway & Miami Rd., Merchantville, N. J.
Faudell, C. L., Orchard Cottage, Wexham St., Stoke Poges, Bucks., England
Ference, M., Jr., 102 Deal Esplanade, Deal, N. J.
Forrester, J. W., 211 Massachusetts Ave., Cambridge 39, Mass.
Hambleton, P. N., 15 W. Lake Ave., Oceanside, N. Y.
Johnstone, C. W., 4501-A Ridgeway Dr., Los Alamos, N. Mex.
Lyndon, W. L., 186 Ardmore Ave., Haddonfield, N. J.
Matare, H. F., Vaucresson, 8 Rue Allouard, Seine Et Oise, France
Scott, G. W., Jr., Research Laboratories, Armstrong Cork Company, Lancaster, Pa.
Tsu, D. S. L., 710/1 Hwang Pi Rd., S., Shanghai 5, China

Transfer to Member

Ahmed, W., Box 2038, Stanford, Calif.
Chenery, P. J., 339 Highbrook Ave., Pelham 65, N. Y.
Cosgrove, T., 1555 Odell St., New York 62, N. Y.
Dilatush, E., Box 472, Mountain View, N. J.
Gallagher, J. D., 1403 Schley Ave., San Antonio 10, Tex.
Harris, J. R., Box 208, R.F.D. 2, Dover, N. J.
Hoadley, J. C., 313 Gambier Pl., Lexington Park, Md.
Kehoe, F. P., Clinton, Ont., Canada
Landeck, J. H., 401 Judson St., Bensonville, Ill.
Marshall, E. G., 140 New Montgomery St., San Francisco, Calif.
Meisinger, H. P., 1121 Vermont Ave., N.W., Washington, D. C.
Schachte, W. L., 152 Grove St., Charleston 22, S. C.
Smith, M. C., U. S. Naval School, (General Line), Monterey, Calif.
Weber, J. P., Jr., 2517 Coyle Ave., Chicago 45, Ill.
Wersen, D. T., 3561 Military Ave., Los Angeles 34, Calif.
Wooley, R. L., 10 Bradford Ct., Syracuse 7, N. Y.

Admission to Member

Banerjee, S. K., High Frequency Laboratory, Ericsson Telephones, Ltd., Beeston, Nottingham, England
Berger, E. W., 1367 University Ave., Stockton, Calif.
Chamberlin, R. M., WGGG, 1230 Waldo Rd., Gainesville, Fla.
deVoogt, A. H., Radio-Section PTT, 6 Scheveningseweg, The Hague, Holland

(Continued on page 64A)

SYLVANIA RECORDING SPECTRORADIOMETER INSURES TOP TELEVISION PICTURE TUBE QUALITY

Measures and Records Degree of Output of All Visible Light Wavelengths in a Few Seconds!

Another Sylvania contribution to the rapidly widening field of television—the recording spectroradiometer—forms a vital link in the rigid quality control of commercial television picture tubes at Sylvania Electric.

This precision instrument accurately plots the energy output of tube screens throughout the entire visible light spectrum in only a few seconds. This is in great contrast to old methods in which a skilled technician had to take and plot hundreds of values, requiring about half a day's work.

Today Sylvania's spectroradiometer, in addition to being a precise production control instrument, is expected to help solve screen standardization problems and provide a scientific tool for screen study. Here's another outstanding product of Sylvania Research Laboratories. Sylvania Electric Products Inc., 500 Fifth Ave., New York 18, N. Y.

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ELECTRONIC DEVICES; CATHODE RAY TUBES; RADIO TUBES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS; PHOTOLAMPS

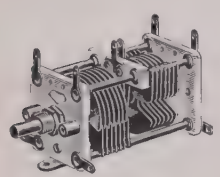
Look AT YOUR SAVINGS
Look AT THESE PRICES

on BUD VARIABLE CONDENSERS

Today is the time to look for savings! Note the prices on our condensers and compare. You will find that the entire Bud line maintains greater value while giving you the best quality and service.

BUD "CE" TYPE DUAL MIDGET CONDENSERS

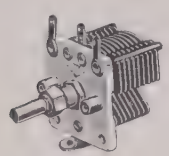
1. Extremely efficient, they embody everything that any other condenser has PLUS a positive rotor wiping contact in the exact electrical and physical center permitting the design of balanced circuits.
2. Ball bearings are featured on this double bearing condenser for centering and elimination of end-play.
3. Any of three methods of mounting can be used.
4. Alignment is maintained by 4 rigid tie rods.
5. Two solder lugs on each stator permit the placement of other components for efficient, short lead design.



Catalog Number	PER SECTION Max. Cap.	Min. Cap.	No. of Plates	Air Gap	Distance Behind Panel	Dealer Cost
CE-2032	35	6	7	.030"	3 1/32"	$2.30
CE-2033	50	7	9	.030"	3 1/4"	2.45
CE-2034	75	8	14	.030"	3 21/32"	2.95
CE-2035	100	9	18	.030"	4 3/32"	3.15
CE-2036	150	10	27	.030"	5 3/16"	3.75
CE-2039	15	5	5	.060"	3 1/32"	2.70
CE-2040	35	7	11	.060"	4 1/32"	3.15
CE-2041	50	8	15	.060"	4 23/32"	3.40

BUD "CE" MIDGET CONDENSERS—SINGLE BEARING

1. Any of the three methods of mounting can be utilized.
2. Extended rotor shaft allows ganging of two or more condensers.
3. Smooth operating and noiseless bearings permit operation on high frequencies and prevent capacity changes.



Catalog Number	Max. Cap. MMFD.	Min. Cap. MMFD.	Air Gap	No. of Plates	Over-all Length	Dealer Cost
CE-2020	15	4	.030"	3	1 11/16"	$1.15
CE-2021	35	6	.030"	7	1 29/32"	1.30
CE-2022	50	7	.030"	9	2 1/32"	1.40
CE-2023	75	8	.030"	14	2 1/4"	1.60
CE-2024	100	9	.030"	18	2 15/32"	1.80
CE-2025	150	10	.030"	27	3"	2.00
CE-2028	15	5	.060"	5	1 15/16"	1.35
CE-2029	35	7	.060"	11	2 7/16"	1.60
CE-2030	50	8	.060"	15	2 25/32"	1.75

Bud Radio, Inc. manufactures and catalogs over 400 different variable condensers for your use. We are ready to quote on special condensers in production quantities. Write for catalog.

See the Bud Display, Booth 231, at the I.R.E. Radio Engineering Show, March 7th to 10th.

BUD *The mark of perfection*

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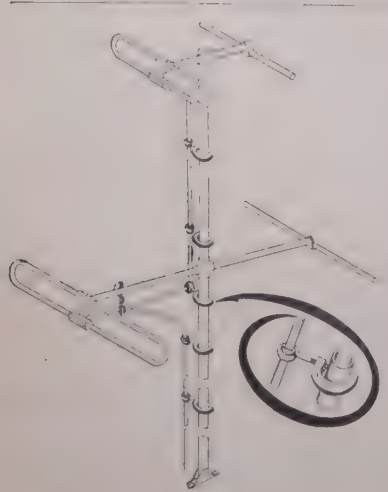

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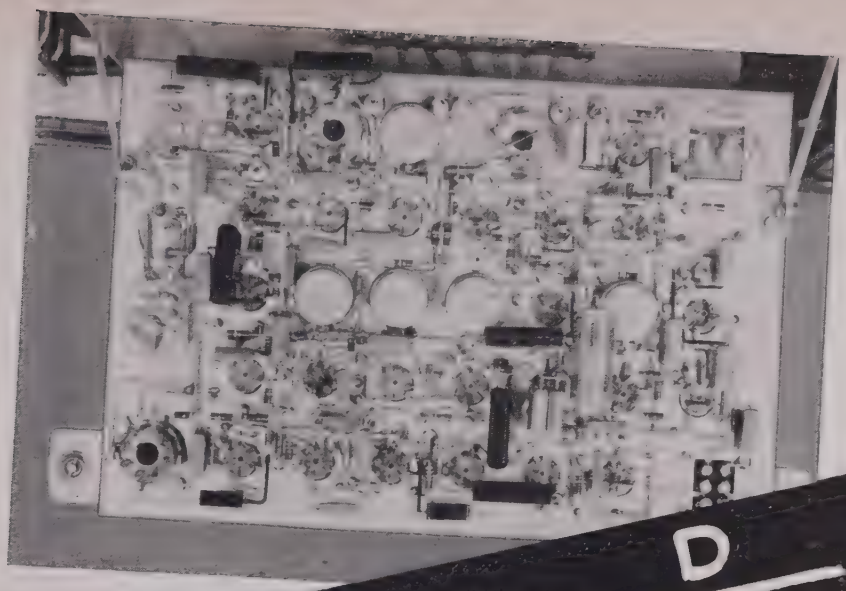
Lakshmanan, T. K., 3331 Army Hall, 1560 Amsterdam Ave., New York 31, N. Y.
Lavo, H. J., 435 Market, South Williamsport, Pa.
Lyke, E. F., 1504 Edgewood Ave., Rochester 10, N. Y.
Marsh, C. R., Electrical Engineering Department, Pennsylvania State College, State College, Pa.
Martin, T. L., Jr., Electrical Engineering Department, University of New Mexico, Albuquerque, N. Mex.
Miller, R. A., 3 Calabria Pl., Dayton 4, Ohio
Mohan, M. M., 550 Riverside Dr., Apt. 62, New York 27, N. Y.
Morgan, S. G., R.A.F., Air Ministry, 17 Monck St., London, S.W. 1, England
Neeve, F. W., R.A.F. Station, Watton, Norfolk, England
Nunn, E. D., Northern Signal Company, Inc., 120 North Broadway, Milwaukee 2, Wis.
Pacini, H. P., 909 Rutger St., Utica, N. Y.
Porter, J. B., 1038 W. Mistletoe, San Antonio 1, Tex.
Proud, E., c/o Office of the Engineer in Chief, Posts & Telegraphs, Box 581, Nairobi, Kenya, East Africa
Rodimon, C. C., Tower Rd., Lincoln, Mass.
Rubin, I. E., 1227 E. Genesee St., Syracuse, N. Y.
Silvertooth, E. W., 1416 N. Marengo Ave., Pasadena 3, Calif.

The following admissions to Associate were approved and were effective as of January 1, 1949:

Alfreds, L. J., Lane Head, Elborough Rd., South, Norwood, London, England
Ataman, A., 1306 S. Orchard, Urbana, Ill.
Barnes, O. C., 2735 Walker, Kansas City 2, Kans.
Bellow, F. T., c/o Radio Station WULA, Eufaula, Ala.
Bendett, R. M., 35-16—76 St., Jackson Heights, L. I., N. Y.
Bidell, F. W., East River Rd., Grand Island, N. Y.
Bright, T. F., 123 Lenox Ave., New Milford, N. J.
Bruce, L. G., 1942 S. Carpenter St., Chicago 8, Ill.
Carnagie, V. F., 411 State St., Brooklyn, N. Y.
Carvajal, H. H., 223 Avda. Brasil, Santiago, Chile
Cooper, R. J. G., 11831—96 St., Edmonston, Alta., Canada
Davis, J. C., Jr., 686 Pleasant St., Framingham Center, Mass.
Dunn, F. S., 2433 Ravenwood Ave., Dayton 6, Ohio
Ebling, W. F., Jr., 3466 Braddock St., Philadelphia, Pa.
Flynt, E. R., Box 3666, Georgia Institute of Technology, Atlanta, Ga.
Foss, W. L., 927 15 St., N.W., Washington 5, D. C.
Freeman, H., Mail Station K39, Sperry Gyroscope Company, Great Neck, L. I., N. Y.
Gabor, W. D., 142 Second St., Keyport, N. J.
Gibbon, W. F. H., 704 E. Stepney Pl., Inglewood, Calif.
Gnagey, L. B., 653 S. Miami St., West Milton, Ohio
Gober, R. H., 1430 Glenwood Ave., S.E., Atlanta, Ga.
Graham, N. L., 998 Center Ave., Lancaster, Pa.
Green, R., 2713 N. 34 St., Milwaukee 10, Wis.
Grometstein, A. A., 94 St. Botolph St., Boston 16, Mass.
Haimowitz, B., 1726 N. Paxon St., Philadelphia 31, Pa.
Hammann, W. M., 75 Converse Ave., Malden 48, Mass.
Harvey, D. M., USAF, Box 1346, Wright Field, Dayton, Ohio

(Continued on page 66A)



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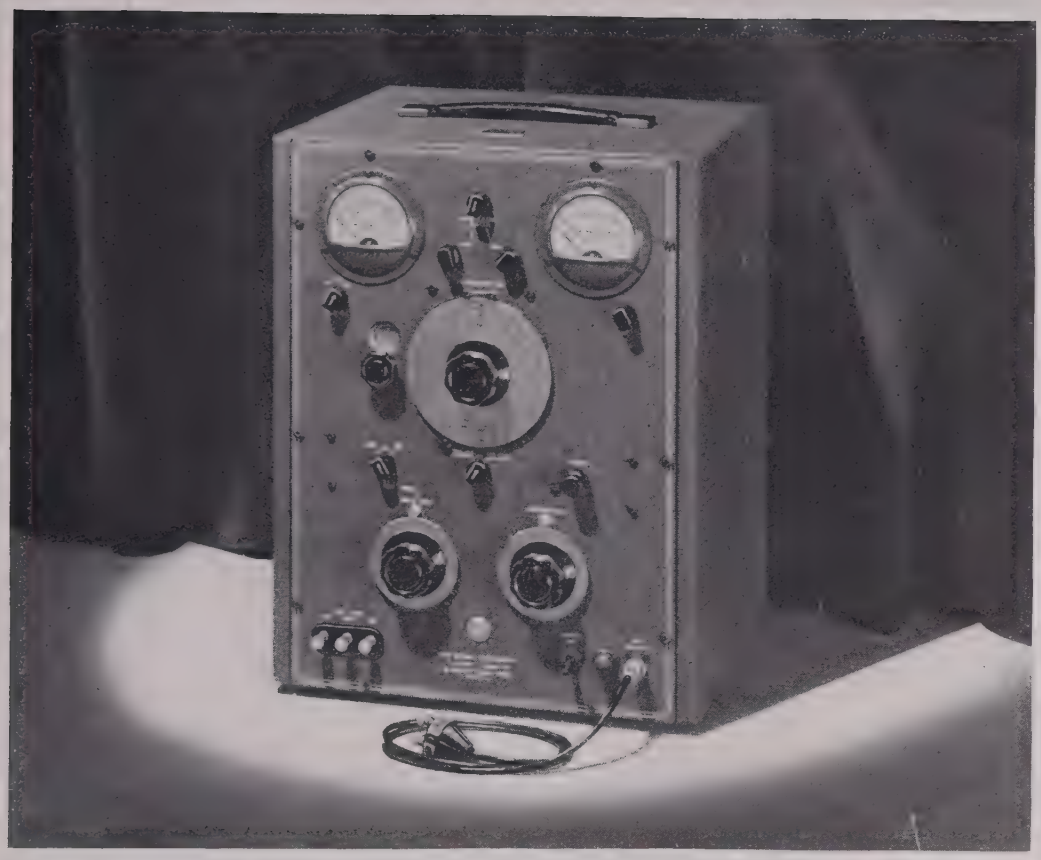
Humphrey, E.L., 1519 W. Estes Ave., Chicago 26, Ill.
Hunt, D. F., Moore School of Electrical Engineering, 200 S. 33 St., Philadelphia 4, Pa.
Jaffe, L. D., 315 Eastern Pkwy., Brooklyn, N. Y.
Jones, T. W., "Sunnerbroc," Sabot, Va.
Kamal, A. K., Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore 3, India
Kean, D. W., 110A Forrestal St., China Lake, Calif.
Kilpinen, R. M., 507 Fullerton Pkwy., Chicago 14, Ill.
Knoerl, J. L., 806 Beach Rd., Buffalo 21, N. Y.
Kovalevski, N. N., 892 Prospect Ave., New York 59, N. Y.
Kramer, E. R., Harris-Magruder, Inc., 1835 K St., N.W., Washington 6, D. C.
Krocke, W. F., 513-C E. South St., Angola, Ind.
Lange, W. G., R.D. 1, Sanborn, N. Y.
Loewen, K. L., 915 N. Eleventh, Manhattan, Kan.
Maertz, W. A., 4723 Kenwood Ave., Chicago 15, Ill.
Mardiks, D., 3900 W. 53 St., Kansas City, Kan.
McAllister, J. A., USN, Sur-AS-Dev-Det., Key West, Fla.
McCool, W. A., 5609 Randolph St., Hyattsville, Md.
Mendenhall, W. S., Jr., 439 Garden Rd., Columbus 12, Ohio
Mitra, S. C., 158/2B Harish Mukherjee Rd., Calcutta 25, India
Mruk, W. F., Jr., 119 Ella St., McKees Rocks, Pa.
Murugasu, V., Ponnalai East, Chulipuram Post, Jaffna, Ceylon
Nagai, H., 936 E. 42 Pl., Chicago 15, Ill.
Neumark, J., T.R. Laboratory, American Television, Inc., 5050 N. Broadway, Chicago 40, Ill.
Newton, R. L., Radio Station WCON, The Atlanta Constitution, Atlanta 2, Ga.
Ogletree, W. A., 616 College Ter., Williamsburg, Va.
Owings, J. L., 503 Baird Rd., Merion Station, Pa.
Pewitt, B. D., 411 Ninth Ave., Haddon Heights, N. J.
Rajaratnam, T., 34 Venkatesa Naick St., George Town, Madras, India
Ransom, A. W., 4429 Duneden Ave., Deer Park, Cincinnati, Ohio
Ransome, R. L., 722 West 30, Houston 18, Tex.
Reeves, P. E., Box 231, Vapor Recovery Systems Company, Compton, Calif.
Roberts, J. M., 5927 S.E. 23 Ave., Portland 2, Ore.
Rozas, F. N., 1612 S. St. Sndrews Pl., Los Angeles 6, Calif.
Saunderson, J. J. G., c/o Central Radio Maintenance, Bryan St., Ballymena, North Ireland
Scholfield, W. D., 179 Bessborough Dr., Toronto, Ont., Canada
Schultz, D. G., 507 Fullerton Pkwy., Chicago 14, Ill.
Schumacher, H. W., 3280 N. Tenth St., Milwaukee 6, Wis.
Seetharam, H. R. B., c/o H. Ramanna, The Mysore Silk Filatures, Ltd., Mysore, Mysore State, India
Sesha-Iyer, C. S., 6 Saraswat Colony, Poona 2, Bombay Prov., India
Silverstein, M. M., 825 E. 49 St., Chicago 15, Ill.
Smith, R. W., Jr., Room 4000, Michelson Laboratory, China Lake, Calif.
Somayajulu, Y. V., Physics Department, Andhra University, Waltair, India
Sotton, V. O., c/o Philippine Consulate, 40 Exchange Pl., New York, N. Y.

(Continued on page 68A)



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Type 202-B · 54-216 megacycles

The Accepted Standard of Performance!

In January, 1946, at the I. R. E. National Convention in New York City, a preliminary engineering model of the type 202-A FM-AM Signal Generator was displayed for the first time. Many well known FM and television engineers, invited to comment frankly on performance specifications, suggested refinements and features which they believed would be most desirable in the finished design.

Utilizing this valuable information, Boonton Radio Corporation's engineers worked another full year before they were ready to place their approval on the final design—the type 202-B FM-AM Signal Generator.

The advantages of this essential instrument were recognized immediately. Since its enthusiastic reception, the 202-B has increased in popularity and today it is generally accepted as the acknowledged standard of FM-AM signal generator performance. Practically every well known radio manufacturing concern is now placing increasing numbers of this versatile instrument in full time use, assisting their engineers and research staffs to design and produce better, lower cost radio and television receiving equipment.

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(Continued from page 66A)

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Stello, P. E., 3619 W. 102 St., Inglewood, Calif.
Weedie, D. A., 608 S.E. 18 St., Portland 14, Ore.
Wahl, R. E., 2031 W. 61 Terrace, Kansas City, Mo.
Whalen, T. J., Jr., 162 Highland Ave., Buffalo 9, N. Y.
White, E. A., Baldwin Manor, Apt. C-11-4, Aberdeen, Md.
Wofford, J. H., 4317-A Montrose Blvd., Houston 6, Tex.
Zentner, J. E., 127 E. 73 St., New York, N. Y.
Zucker, M. J., 4910 N. Karlov Ave., Chicago 30, Ill.

The following transfers to Associate grade were approved to be effective as of January 1, 1949:

Anderson, T. N., 9 Cottage Lane, Huntington Station, N. Y.
Ariessohn, E. R., 96-11—65 Rd., Forest Hills, L. I., N. Y.
Aucremanne, M. J., 18 Whitney Ave., Floral Park, L. I. N. Y.
Baer, T. M., 875 West End Ave., New York 25, N. Y.
Brorein, W. J., Southern Bell Telephone & Telegraph Company, Division Engineer Office, 1630 Lynch Bldg., Jacksonville, Fla.
Brown, G. L., 416 West St., Stillwater, Okla.
Brown, I., 835 N. Seventh St., Camden, N. J.
Buerger, E. J., 325 Mohawk Ave., Scotia 2, N. Y.
Carpenter, J. W., 207 E. Second St., Austin, Tex.
Cattermole, G. B., ComAirLant Staff, Naval Air Station, Norfolk 11, Va.
Cerino, R., 278 First Ave., New York 9, N. Y.
Conroy, G. J., 2644 Glenmawr Ave., Pittsburgh 4, Pa.
Cummings, K. C., 2212 Aldrich Ave. S., Minneapolis 5, Minn.
Dawson, E. B., Savannah Armature Works, Inc., 126 W. Bay St., Savannah, Ga.
Dazey, M. H., 933 Richmond St., El Cerrito, Calif.
Dennison, P. R., 1539 Maple St., Pasadena 5, Calif.
Emmons, A. W., 1308 S. Ridgewood Ave., Daytona Beach, Fla.
Evans, W. E., Jr., 2281—12 Ave., Sacramento Calif.
Fee, D. R., 125 Main St., Orange, N. J.
Frisch, F. W., 418 Kelby St., Fort Lee, N. J.
Gartzke, F. J., 1812 Morningside Dr., Iowa City, Iowa
Gellert, J., 181 Lenox Rd., Brooklyn 26, N. Y.
Greenhill, C. W., 1144—22 St., San Diego 2, Calif.
Grim, W. M., Jr., Massachusetts Institute of Technology, Servo Laboratory Bldg. 32, Cambridge 39, Mass.
Hegde, K. S., Department of Tele-Communications, College of Engineering, Madras 15, India
Hofhelmer, R. W., 5 W. 86 St., New York 24, N. Y.
Jesurun, M. M., 1263 Cole St., Columbus 5, Ohio
Keyes, W. R., Jr., 4021 Greenwood Ave., Oakland 2, Calif.
Kingsley, B., 968 Bronx Park South, New York 60, N. Y.
Knight, S. J., Jr., 3040 E. Exposition Ave., Denver 9, Col.
Kramer, S. I., 2340 Valentine Ave., New York 57, N. Y.
Krilanovich, N. J., 725 Fern Pl., N.W., Washington 12, D. C.
La Rosa, R., 267 Bedell Ter., West Hempstead, L. I., N. Y.
Lowell, R., Naval Research Laboratory, Code 3422, Washington 20, D. C.
Martin, F. C., Jr., U. S. Navy Electronics Laboratory, Code 413 C, Bldg. 128, San Diego 52, Calif.
McBrian, J. E., 33 Oldwood Rd., Port Washington, L. I., N. Y.
McFarlin, F. E., 600 S. 14 St., Ponca City, Okla.
Mendel, F. S., 1579 S. 60 St., Milwaukee 14, Wis.
Menes, M., 68 W. 107 St., New York 25, N. Y.
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(Continued from page 70A)

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MODEL 2451

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$76.50

includes crystal Probe good to 125 MC.

This new vacuum tube Volt-Ohm-Milliammeter incorporates features previously found only in the most expensive equipment.

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CHECK THESE FEATURES

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2. *Simplified balancing . . . merely zero on range to be used and proceed.*
3. *Large 6" 200 Microampere Red • Life-Time Meter guarantee against defective workmanship or material.*
5. *6 inch scale length at top arc.*
4. *Zero center voltage scale provided for F. M. discriminator alignment.*
5. *Imput impedance 11 Megohms on D.C. Volts; approx. 4.8 Megohms on A.C. and R.F. Volts.*

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D.C.-A.C.-A.F. VOLTS:	0-2.5-10-50-250-500-1000
R.F. VOLTS:	0-2.5-10-50
D.C. MILLIAMPERES:	0-2.5-10-50-250-500-1000
OHMS:	0-1K-10K-100K
MEGOHMS:	0-1-10-1000

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(Plugs in same socket without change of connection . . . frequencies up to 400 MC.)

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(Continued from page 68A)

Pattee, H. E., 7336 Jackson Ave., Hammond, Ind.
Perry, M. A., 565 Crown St., Brooklyn 13, N. Y.
Pughe, E. W., Jr., 3828 Brookside Rd., Toledo 6, Ohio
Reddeck, J. G., RCA Laboratories, Princeton, N. J.
Robinson, K. W., 33 Vandeventer Ave., Princeton, N. J.
Robison, W. C., Box 464 Mount Ayr, Iowa
Rosenberg, J. M., 1962 Hoover Ave., Oakland 2, Calif.
Sackler, A. A., c/o Ebasco Services Inc., Rm. 1356, 2 Rector St., New York 6, N. Y.
Scarbrough, A. D., Ave. F & 6 St., Yucaipa, Calif.
Schmitzer, R. W., 2014 E. Windsor Pl., Milwaukee 2, Wis.
Schwarzkopf, J., 51 Verdun Ave., New Rochelle, N. Y.
Seaward, P. E., U. S. Naval Electronics Laboratory, Bldg. 328, San Diego 52, Calif.
Sencenbaugh, D. W., Staff, Commander Submarine, Atlantic Fleet, New London, Conn.
Simmons, J. M., Jr., Box 966, Seagraves, Tex.
Smith, R. A., 989 Cliff Dr., Laguna Beach, Calif.
Sumpter, C. B., Jr., 4373 Fort Ave., Lynchburg, Va.
Sweet, R. G., 2035 Kenilworth Ave., Los Angeles 26, Calif.
Taber, J. E., 824 Doan Dr., Burbank, Calif.
Teeple, R. P., 1481 E. Rock Springs Rd., N.E., Apt. 1, Atlanta, Ga.
Tobin, M. W., 7 Stuyvesant Oval, Apt. 7-A, New York 9, N. Y.
Tuttle, F. M., 585 Page Ave., N.E., Atlanta, Ga.
Underwood, J. F., 1972 Welton Ave., New York 53, N. Y.
Van Nice, R. I., 5212 Forbes St., Pittsburgh 17, Pa.
Vreeland, R. W., 36 Magee Ave., Mill Valley, Calif.
Wade, O., 791 E. Washington St., Pasadena 6, Calif.
Waldron, T. J., 67 Richmond Hill, New Canaan, Conn.
Walker, B., 354 Ocean Ave., Brooklyn 26, N. Y.
Weber, J. W., 402 E. Walnut, Kokomo, Ind.
Weise, D. M., 2014 E. Genesse St., Syracuse, N. Y.
Wilson, R. M., Electronic Research & Development, Ansco, Binghamton, N. Y.
Zellmer, N. A., 701 W. Broadway, Brownfield, Tex.

The following transfers to Associate grade were approved to be effective as of December 1, 1948:

Berl, S., 409 Throop Ave., Brooklyn 21, N. Y.
Brearley, H. C., Jr., 703 Fountain Pl., Burlington, N. C.
Conley, P., Westinghouse Research Laboratory, East Pittsburgh, Pa.
Daggett, N. L., 44 Bay View St., Hyannis, Mass.
Garcia, A., 837 E. Mulberry St., Evansville, Ind.
McGill, D. R., 14612 Summit Dr., Edmonton, Alta, Canada
Y9kelson, B. J., 2301 Kings Highway, Brooklyn 29, N. Y.

The following admissions to Associate grade were approved to be effective as of December 1, 1948:

Appuhamy, F. A., "San Jose," Dankotvwa, Ceylon
Ardelian, T. E., Fur Trade Department (Radio), Hudson's Bay Co., Winnipeg, Mani., Canada
Barnett, H. A., Jr., Radio Station WIST, Charlotte 2, N. C.
Beyer, A. R., 2019 Dunstan, Holiston 5, Tex.
Christopher, O., Box 68, Air Base Branch, Belleville, Ill.
Cooper, L. V., 1930 AACS, APO 731, c/o Postmaster, Seattle, Wash.
Croumlich, R. M., Box 171, New Baden, Ill.
Da Prato, B. F., 505 E. Broad St., Angola, Ind.
Dickens, J. A., E. 56 & Easton Blvd., Des Moines 17, Iowa
Dickinson, I. E., McClatchy Broadcasting Co., 7 & Eye Sts., Sacramento, Calif.
Elam, F. E., 1345 Madison St., N.W., Washington 11, D. C.

(Continued on page 72A)

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A REVOLUTIONARY NEW SPACE-SAVING CONDENSER PAPER WITH AMAZING SELF-HEALING QUALITIES.

SMITH'S New-type Metallized Condenser Paper not only reduces space factor by eliminating the use of electrodes, but gives longer life, higher dielectric strength, and ends forever the disastrous effects of breakdowns.

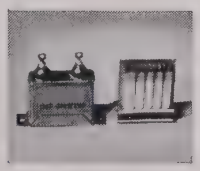
NEW!!! NEW!!! Never before has anything like Smith Metallized Condenser Paper been offered the Electric and Electronic Industries.

It's here! Today . . . now . . . Smith Paper, Inc. makes available its new Metallized Condenser Paper that bids fair to revolutionize the entire electric and electronic field. Smith Metallized Condenser Paper makes possible the first one-layer condenser with an .0003" dielectric material. It also makes possible a 75% saving in space factor over most conventional capacitors. And because of its self-healing characteristics it almost completely eliminates the factor of conducting particles and the usual serious effect of a breakdown.

Answers a long-unfilled need. Design engineers since earliest days of the capacitor industry have sought capacitors that would provide higher capacities, smaller space factors, higher dielectric strength, longer life characteristics, and the elimination of breakdown causes. Since such improvements in design have been limited by the dielectric materials available, the introduction of Smith's Metallized Paper will prove a great boon towards the attainment of these special characteristics. This industry-sought paper not only permits 75% savings in space factor, but also provides other extraordinary advantages.

Increased insulation resistance. It has been found in the manufacture of metallized paper that by covering the base Kraft Condenser sheet with an extremely thin, continuous and uniform film of lacquer, a marked increase in insulation resistance is obtained. This lacquering causes an increase in the thickness of .00030 condenser paper of .03 - .05 mils; while the succeeding zinc coating operation causes an increase in thickness of 3 - 5 millionths of an inch.

Metallized Paper



1 MFD—400 WVDC

4 MFD—150 WVDC

Capacitor samples courtesy Solar Manufacturing Corp., North Bergen, N. J.

Self-healing on breakdowns. Another of the outstanding properties of metallized paper is its capacity to self-heal on a breakdown. In other words, a capacitor wound with metallized paper may be brought to a breakdown voltage, but the effects of the breakdown are sufficient to cause a re-insulation around the breakdown area so that the capacitor is satisfactory for continued use. Numerous breakdowns do not appear to impair this self-healing characteristic. Smith Paper, by taking advantage of this property, is able to furnish a metallized paper devoid of particles which are conducting at the usual test voltages.

Automatically Controlled. Today equipment has been perfected for automatically controlling and continuously recording (where necessary) such properties as lacquer thickness and consistency, thickness of the metal layer, color and resistance of the metal layer, width of margin, etc. — all important characteristics of the product, the close control of which is essential for the best design and manufacture of metallized paper capacitors.

Complete facts available. All facts on Smith Metallized Condenser Paper as it applies to your industry may be had on request. Simply address Smith Paper, Inc., Lee, Massachusetts. There is no obligation.

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(Continued from page 70A)

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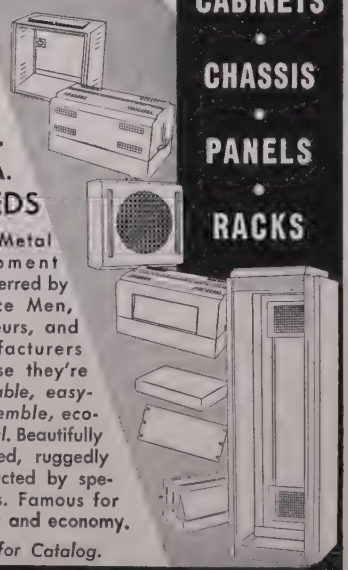

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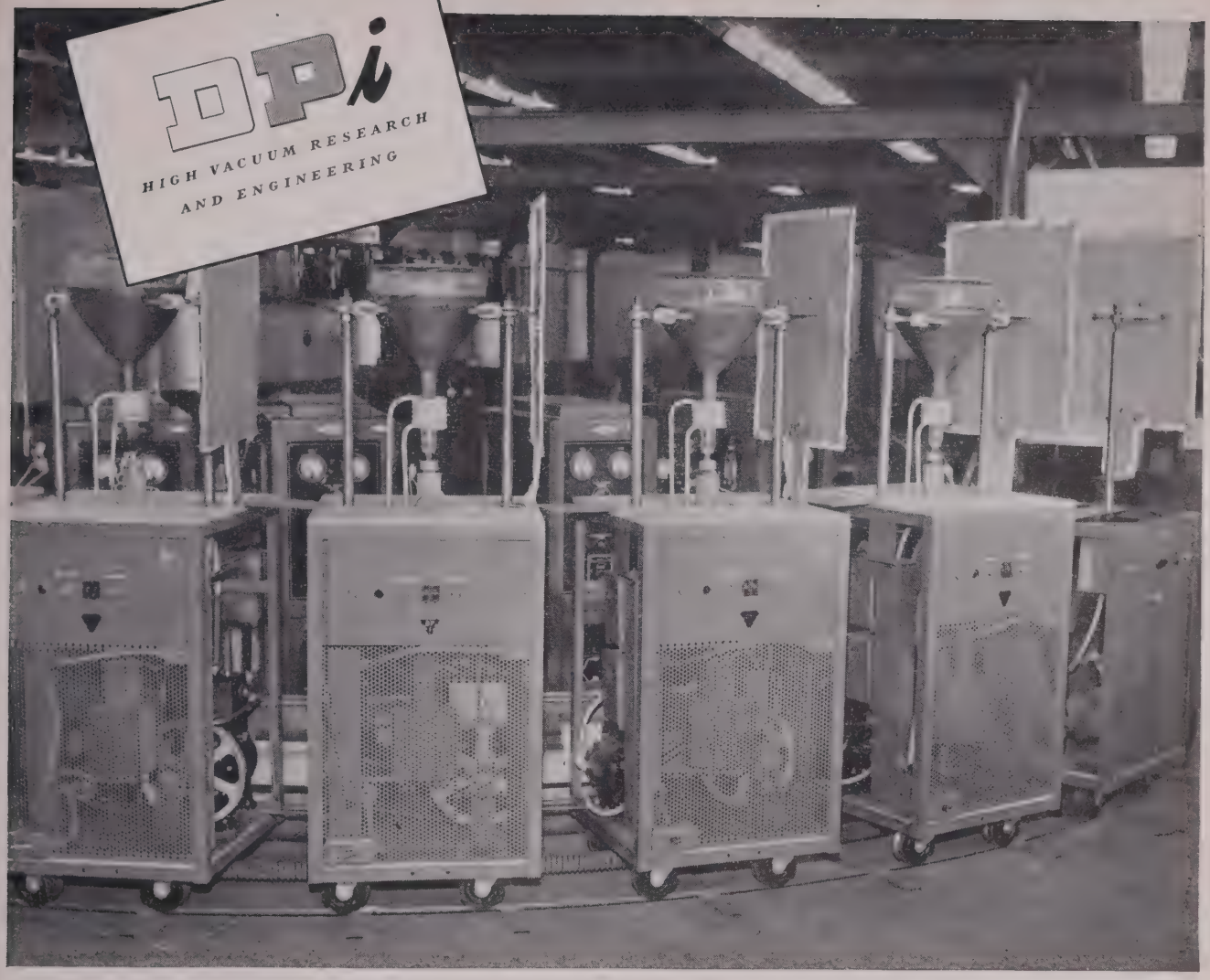
AND ENGINEERING



Breaking the bottleneck of cathode ray tubes

PRODUCTION of picture tubes for television receivers is being speeded up by installation of DPI vacuum systems like the one pictured above. This in-line system is being used for quantity production at the Lansdale Tube Company of Philco Corporation.

A typical exhaust unit will be on display at our booths at the I.R.E. Show at Grand Central Palace, March 7-10. Stop in and see the latest developments in tube processing.

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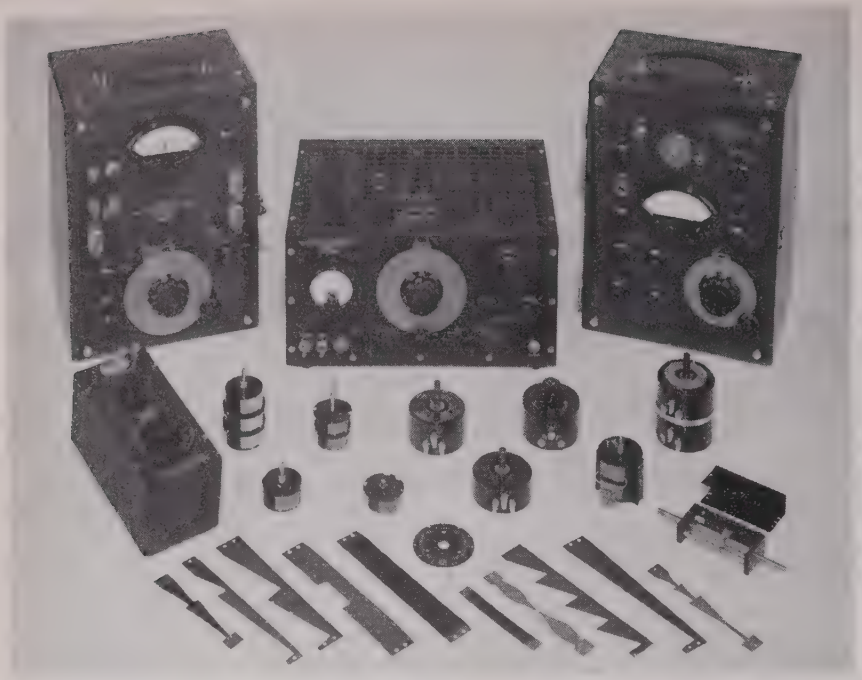

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For audio-frequency impedance and phase angle analysis of circuit elements and complex networks containing electrical or mechanical resonance. Also for general laboratory measurements of R, L and C.

TYPE 311-A Z-ANGLE METER—100 kc to 2 mc.

For radio-frequency impedance and phase angle measurements of transmission lines and broadcast antennas and for general circuit analysis.

TYPE 410-A R-F OSCILLATOR—100 kc. to 2 mc.

A power oscillator for use as a bridge driver and for general laboratory measurements.
Features: high output . . . 50-60Ω output impedance . . . high accuracy and stability . . . expanded frequency scale . . . direct reading output voltmeter having a range of 0 to 50 volts.

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Ranges: 0-11,000Ω and O-110,000Ω
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Directory of 200 Exhibits

(Continued from page 22A)

Firm	Booth
Glaser Lead Co., Inc., Brooklyn, N. Y. Solders and fluxes, lectron rosin core solders.	260
Gray Research & Development Co., Hartford, Conn. Variable speed turntables, sound effects turntable, transcription, turntables, New LP tone arm, transcription tone arms.	X
Graybar Elec. Co., Inc., New York, N. Y. Distributing Machlett and Western Electric vacuum tubes.	96 & 97
Haydu Brothers, Plainfield, N. J. Small metal stampings, precision machined parts, drawn and pressed parts, screw machine parts, formed wire parts, gas, oxygen and air burners.	211
Helipot Corp., So. Pasadena, Calif. Helipot potentiometers, Beckman Duodials, Continuous rotation potentiometers, Multitap Potentiometers.	243
Hewlett-Packard Co., Palo Alto, Calif. Electronic test equipment and will feature 805A Slotted Line, 430A Microwave power meter, 614A Signal generator, new instruments.	40 & 41
Hickok Electrical Inst. Co., Cleveland, Ohio Electrical indicating meters and electronic test equipment.	232
Hopkins Engineering Co., Detroit, Mich. Stoddart Aircraft Radio Co. products.	56
Indiana Steel Products Co., Chicago, Ill. Permanent magnets, cast and sintered magnetic tape recording heads, magnetic recording tape.	279

(Continued on page 76A)

New! **JOHNSON**

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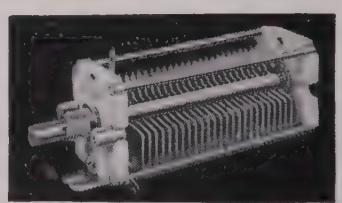
CERAMIC SOLDERED FOR STABILITY-STRENGTH



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Spacing .030" and .080"
New Bright Alloy Plating

In addition, the JOHNSON Type L Variables feature a new bright alloy plating that is extremely corrosion resistant, even under extreme climatic conditions.

JOHNSON also makes Type L Variables in Dual, Differential and Butterfly types in many different models.

All are ceramic soldered. There is nothing to work loose causing stator wobble and fluctuations in capacities.

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JOHNSON
a famous name in Radio
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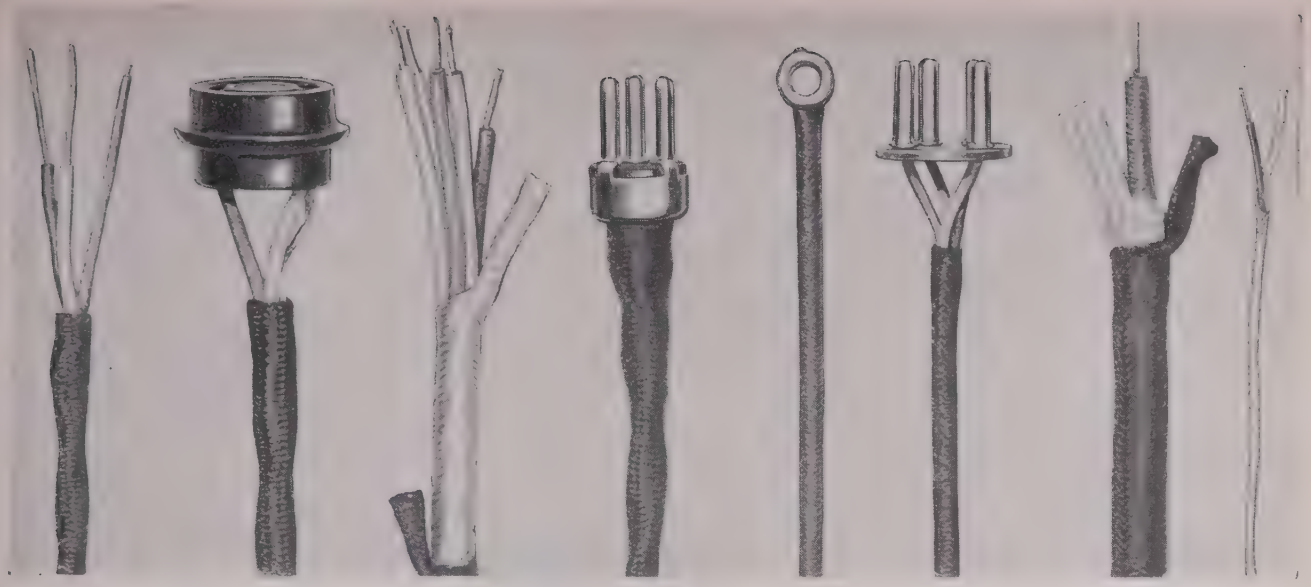

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LENZ THE *lifeline* OF ELECTRONIC EQUIPMENT

When you list the qualities most desirable in a supplier of wires and cables for your electronic equipment, you will find that Lenz most nearly answers your description of a dependable source.

First, this company has the engineering background and experience, the knowledge of your requirements in wires and cables that are needed to help draft your specifications.

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Third, it is a reliable organization with over 40 years background of dependable service to the communications industry.

Make Lenz your principal source for wires and cables. A Lenz wire engineer will gladly consult with you regarding your special requirements. Correspondence is invited.

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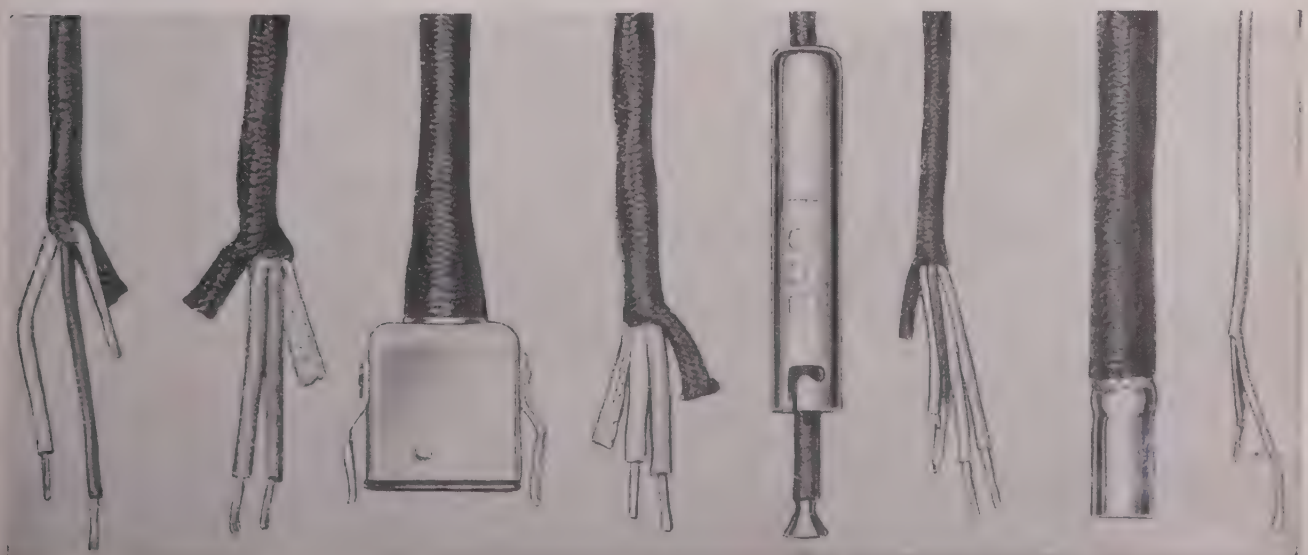

Simplify WITH S.S.WHITE FLEXIBLE SHAFTS

THE location of condensers and other variable elements in electronic equipment is pretty definitely fixed by considerations of circuit efficiency, easy assembly and wiring.

Likewise, the location of their control knobs is fixed by considerations of convenient operation and harmonious panel appearance.

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(Continued from page 74A)

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Industrial Products Co., Danbury, Conn. Coaxial connectors, RF components, panel connectors, antennas.	223–226
Industrial Television Inc., Clifton, N. J. Remote control public view television receivers, hotel television systems TV station monitors antenna distribution systems.	285
International Nickel Co., Inc., New York, N. Y. Applications of nickel and nickel alloys in electronic industries.	98 & 99
International Resistance Co., Philadeophia, Pa. Composition Carbon Resistors, high stability resistors, carbon resistors, high frequency resistors, high voltage resistors, precision resistors.	102
J-B-T Instruments, Inc., New Haven, Conn. Vibrating Reed frequency meters, and testers, rotary selector switches, appliance temperature testers, Shurite AC and DC Panel and Pocket Meters.	254
J. F. D. Manufacturing Co., Inc., Brooklyn, N. Y. TV–FM Antennas, Brackets, Accessories, radio parts and accessories.	266
Howard B. Jones Div., Cinch Mfg. Corp., Chicago, Ill. Tube Sockets, Multi-Contact Plugs and Sockets, Terminal strips, terminals.	257

(Continued on page 77A)

AMPERITE

Studio Microphones at P.A. Prices

Ideal for BROADCASTING RECORDING PUBLIC ADDRESS

"The ultimate in microphone quality," says Evan Rushing, sound engineer of the Hotel New Yorker.

- *Shout* right into the new Amperite Microphone—or *stand 2 feet away*—reproduction is *always perfect.*
- *Not affected by any climatic conditions.*
- *Guaranteed to withstand severe "knocking around."*

Models
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List $42.00

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Jim Lansing Signature Speakers will provide an almost unbelievable realism. The experience gained through a quarter of a century of leadership in the sound reproduction field has gone into their development and design. For maximum dynamic range and frequency response compare Jim Lansing Signature Speakers before you buy.

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Designed especially for music systems and public address use. Has exceptionally high efficiency. Recommended for operation and frequencies from 60 to 6500 C.P.S. with a maximum usable range of 40 to 15000 C.P.S.

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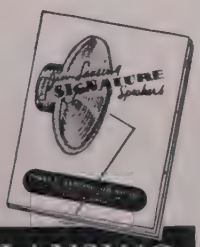

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Directory of 200 Exhibits

(Continued from page 76A)

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Karp Metal Products Co., Inc., Brooklyn, N. Y. Sheet Metal Cabinets, Housings and consoles for electronic equipment.	49 & 50
Kay Electric Co., Pine Brook, N. J. Wide range sweeping oscillators, ultra short pulse generators, VHF spectrum analyzer, television test equipment, sound spectrograph.	22
Kenyon Transformer Co., Inc., New York, N. Y. Transformers and reactors for broadcast, commercial, and government service.	Y
Kester Solder Co., Chicago, Ill. Kester "Resin-Five" Core solder—other Kester flux core solders, solid wire and bar solders, also solder preforms and fluxes.	253
Kimble Glass Div., Owens-Illinois Glass Co., Toledo, Ohio Kimble Glass Cathode Ray bulbs for the television industry.	90
Kings Electronics Co., Inc., Brooklyn, N. Y. Connectors, antennas, variable condensers.	L
James Knights Co., Sandwich, Ill. Quartz Crystals, crystal holders, frequency standards.	I
LaPointe Plascamold, Inc., Unionville, Conn. Television Antennas, Masts, Towers, and Accessories.	306
Lavoie Labs, Morganville, N. J. Oscilloscopes, Signal Generators, Wave meters Sound Embossers.	87 & 88
Linde Air Products Co., New York, N. Y. Linde Xenon, Krypton, Argon, Neon, Helium, rare gas mixtures, synthetic sapphire boules, rods, balls, centerless-ground rounds, Synthetic rutile.	51
Littelfuse, Inc., Chicago, Ill. Instrument Fuses, indicating lights, high voltage fuses, circuit breakers.	273
Lord Mfg. Co., Erie, Pa. Rubber Insulation and Vibration Mountings	317
M B Mfg. Co., Inc., New Haven, Conn. Vibration testing equipment, vibration pickup, vibration isolators.	250
McGraw-Hill Publishing Co., New York, N. Y. Electronics, Nucleonics, McGraw-Hill Book Co.	200
Machlett Laboratories, Inc., Springdale, Conn. Electron tubes for broadcast industry and special purposes.	96 & 97
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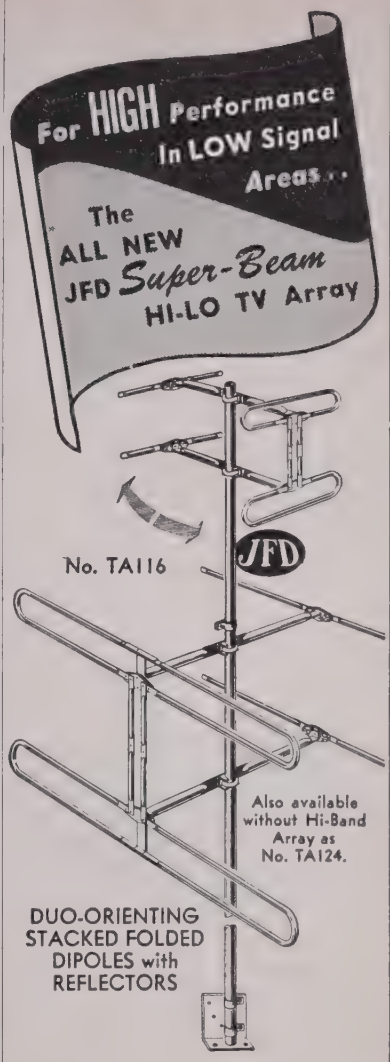
Microwave Equipment Co., Verona, N. J. Microwave Equipment, Waveguide components and test equipment.	305
August E. Miller (Laboratories), North Bergen, N. J. Frequency Control Units .001% to .0001% accuracy, Miniature Crystal Ovens, Quartz Crystals and electronic telegraph equipment.	308

(Continued on page 78A)



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Cleveland - Pittsburgh	120
New Haven - New York	110
San Diego - Los Angeles	100
South Bend - Chicago	90

OUTSTANDING FEATURES!

- ✓ Gives full 12 channel TV reception plus FM.
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- ✓ U-Bolt Clamp construction provides 1/8, 1/4 or 1/2 wavelength spacing of 2, 4, 6, or more bays on mast for tremendous stacking flexibility — also permits independent orientation of each bay.
- ✓ Lightning-fast assembly time.
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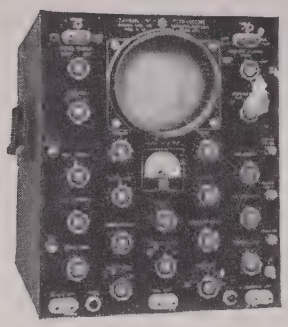

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Designed for maximum usefulness in laboratories doing a variety of research work, this instrument is suited to radar, television, communication, facsimile, and applications involving extremely short pulses or transients. It provides a variety of time bases, triggers, phasing and delay circuits, and extended-range amplifiers in combination with all standard oscilloscope functions.

THESE FEATURES ARE IMPORTANT TO YOU

- Extended-range amplifiers: vertical, flat within 3 db 5 cycles to 6 megacycles; horizontal, flat within 1 db 5 cycles to 1 megacycle.
- High sensitivity: vertical, 0.05 RMS volts per inch; horizontal 0.1 RMS volts per inch.
- Single-sweep triggered time base permits observation of transients or irregularly recurring phenomena.
- Variable delay circuit usable with external or internal trigger or separate from 'scope.
- Sawtooth sweep range covers 5 cycles to 500 kilocycles per second.
- 4,000 volt acceleration gives superior intensity and definition.

For complete data, request Bulletin 4810-RO

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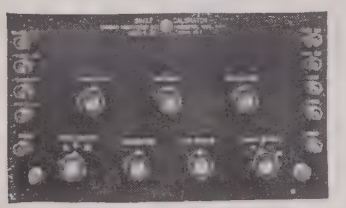


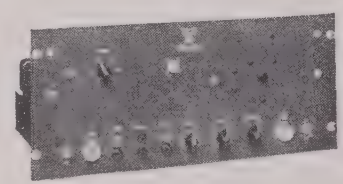
Model GL-22

This versatile source of timing markers provides these requisites for accurate time and frequency measurements with an oscilloscope:

- Positive and negative markers at 0.1, 0.5, 1.0, 10, and 100 microseconds.
- Marker amplitude variable to 50 volts.
- Gate having variable width and amplitude for blanking or timing.
- Trigger generator with positive and negative outputs.

Further details are given in Bulletin 4810-RC.

SQUARE-WAVE MODULATOR AND POWER SUPPLY



Model TVN-7

Here is the heart of a super high frequency signal generator with square wave, FM, or pulse modulation. Provides for grid pulse modulation to 60 volts, reflector pulse modulation to 100 volts, square wave modulation from 600 to 2,500 cycles. Voltage-regulated power supply continuously variable 280-480 or 180—300 volts dc. For additional data and application notes, see Bulletin 4810-RM.

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Model TAA-16

Write for Bulletin 4810-RA containing full details of this useful instrument.

- Standing wave voltage ratios are read directly on the panel meter of this sensitive, accurate measuring instrument.
- Frequency range 500 to 5,000 cycles per second.
- Two input channels with separate gain control for each.
- "Wide-band" sensitivity 15 microvolts full scale.
- "Selective" sensitivity 10 microvolts full scale.
- Bolometer/crystal switch adjusts input circuit to signal source.

In Canada, address Measurement Engineering Ltd., Arnprior, Ontario.

BROWNING Laboratories, Inc. Winchester, Mass.

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Directory of 200 Exhibits

(Continued from page 77A)

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Mycalex Corp. of America, Clifton, N. J. Glass-bonded mica, the "Mycalex" products.	82
National Carbon Co., Inc., New York, N. Y. Radio batteries, hearing aid batteries, batteries for radiation detectors.	52 & 53
National Company, Inc., Malden, Mass. Commercial, communications receivers, electronic components and assemblies, including television receivers.	83 & 84A
National Research Corp., Cambridge, Mass. High vacuum equipment, diffusion pumps, vacuum gauges, valves, special equipment.	217
National Research Council, Ottawa, Canada Nuclear Instrumentation.	336
National Technical Labs, So. Pasadena, Calif. Mx Series Portable Radiation Instruments both Ionization and GM Tubes.	337
Northern Radio Co., Inc., New York, N. Y. Complete line of frequency shift equipment such as: Diversity receivers, F. S. Keyers, Converters, Tone Keyers and Filters.	275 & 276
Nuclear Inst. & Chem. Corp., Chicago, Ill. Scalers, geiger counters, accessories.	330
Nucleonics, New York, N. Y. Magazines.	200
Oak Ridge Antennas, New York. N. Y. Television Antennas.	274A

(Continued on page 79A)

New! **JOHNSON**

TYPE L VARIABLES

CERAMIC SOLDERED FOR STABILITY-STRENGTH

DIFFERENTIAL TYPE

Available in Three Models:

2.8 to 11 mmf, 3.5 to 27 mmf, 4.6 to 51 mmf.

Spacing .030" and .080"

Silent Bearings

Silent operation on the highest frequencies is assured with a split sleeve tension bearing that also prevents capacity fluctuation. Tension is constant —contact positive.

JOHNSON also makes Type L Variables in Single, Dual and Butterfly types in many different models.

All are ceramic soldered. There is nothing to work loose causing stator wobble and fluctuations in capacities.

Write for New Johnson Type L Variable Catalog Today!

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a famous name in Radio

E. F. JOHNSON CO., WASECA, MINN.

What to SEE at the 1949 Radio Engineering Show

Directory of 200 Exhibits

(Continued from page 78A)

Firm	Booth
Panoramic Radio Corp., Mount Vernon, N. Y. Scanning instruments covering sonic and radio frequency ranges.	241 & 242
Par-Metal Products Corp., Long Island City, N. Y. Relay racks, cabinets, panels, chassis, metal parts.	212
Patton-MacGuyer Co., Providence, R. I. Terminal attaching machine in operation. Terminals for electric wires.	294
Philco Corp., Philadelphia, Pa. Microwave television relay equipment, loran, mobile radio communications systems, laboratory products.	44
Philmore Mfg. Co., New York, N. Y. Television Front Ends.	213
Polarad Electronics Co., New York, N. Y. Television and test equipment.	J
Polytechnic Research and Dev. Co., Inc., Brooklyn, N. Y. Microwave test equipment, variable attenuators, slotted sections and probes and frequency meters of novel design.	261
Potter & Brumfield Sales Co., Chicago, Ill. Relays.	252
Precision Apparatus Co., Inc., Elmhurst, L. I. Wide band sweep signal generator, 5" cathode ray oscillograph multi-range high sensitivity vacuum tube voltmeter.	222
Premier Crystal Labs., Inc., New York, N. Y. Quartz crystal units quartz crystal blanks, crystal controlled oscillators, Temperature control Crystal Units.	318
Presto Recording Corp., Paramus, N. J. Gear driven recorders and transcription turntables. microgroove recorders, amplifiers, blank discs, microgroove turntables.	25 & 26
Pyramid Electric Co., Paterson, N. J. Electrolytic capacitors, paper capacitors, radio-noise suppressors.	208
Radiart Corp., Cleveland, Ohio Vibrators, television antennas, car aerials, vibrator power supplies, inverters, heavy duty vibrators.	296
Radio Corp. of America, Camden, N. J. Broadcast Equipment (AM-FM-TV), Tubes, parts and test equipment.	4–9
Radio-Electronics, New York, N. Y. Radio-Electronics Magazines, Gersback library of radio technical books.	322
Radio Engineering Labs., Long Island City, N. Y. Complete Broadcast Systems FM Broadcast Transmitters Serrasoid Modulator, Studio to Transmitter Link Equip., Educational Transmitter.	323–326
Radio Magazines, Inc., New York, N. Y. Magazines.	94A
Rangertone, Inc., Newark, N. J. Hi Fidelity Broadcast tape recorders.	V
Raytheon Mfg. Co., Waltham, Mass. Receiving, Special Purpose, Subminiature and Microwave Tubes, Microwave communications equipment, and stabilizers.	13
Reeves Instrument Corp., New York, N. Y. Reeves Electronic Analog Computer, Servo mechanisms, components (motors, amplifiers, mechanical parts) verticle gyro.	35
Rek-O-Kut Company, Inc., Long Island City, N. Y. "Challanger" disc recorder, LP-12–dual speed transcription turntable, T-12–12" dual speed transcription turntable.	H

(Continued on page 80A)

Now! Specify **KENYON**

KENYON one of the oldest names in transformers, offers high quality specification transformers custom-built to your requirements. For over 20 years the KENYON "K" has been a sign of skillful engineering, progressive design and sound construction.

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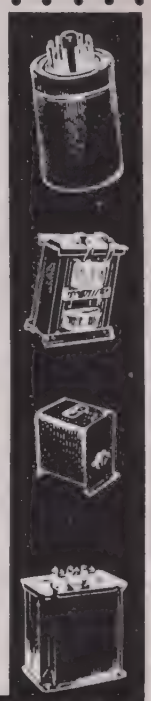

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Budget **S-T-R-E-T-C-H-E-R-S**

PRECISION RESISTORS

1% OR BETTER

Any order for 100 pieces 10% off
Any order for 1,000 pieces 20% off

¼ WATT—25¢

6.68Ω	12.32Ω	16.37Ω	123.8Ω	414.3Ω
10.18	13.02	20.	147.5	705
10.84	13.52	62.54	220.4	2193
11.25	13.89	79.81	301.8	10,000
11.74	14.98	105.8	366.6	59,148

½ WATT—25¢

.250Ω	11.1Ω	235Ω	4,451Ω	15,000Ω
.334	13.15	260	5,000	15,750
.502	46	270	5,900	17,000
.555	52	298.3	6,500	20,000
.627	55.1	400	7,000	25,000
.76	75	723.1	7,500	30,000
1.01	97.8	2,500	8,000	37,000
1.53	125	2,850	8,500	100,000
2.04	180	3,427	10,000	150,000
2.25	210	4,000	14,825	

1 WATT—30¢

1.01Ω	5.21Ω	1.250Ω	9,000Ω	55,000Ω
2.58	10.1	3,300	18,000	65,000
3.39	16.9			70,000
5.05	270	7,000	50,000	75,000

1 WATT—40¢

100.000Ω	128.000Ω	180.000Ω	470.000Ω	525.000Ω
120,000	130,000	250,000	500,000	600,000
125,000	160,000	320,000	522,000	700,000

1 Megohm, 1 Watt, 1%—65¢; 5%—40¢

PRECISION POTENTIOMETERS

20,000	Muter	314A	$1.70
20,000	GR	314A	2.50
10,000	Muter	471T	2.35
10,000	DJ	292	.95
10,000	GR	371T	2.50
10,000	GR	471A	3.50
6,000	Muter	314A	1.70
6,000	DJ	260	1.70
6,000	GR	314A	2.50
5,000	Muter	314A	1.70
5,000	DJ	271T	2.00
5,000	GR	314	2.50
2,000	Muter	314A	1.70
2,000	DJ	260	1.70
1,000	GR	314A	2.50
50	DJ	292	.75
20	GR	301	1.10
12	DJ	292	.75

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X124T2-UTAH, Mkd. 9262 or 9280 ....$1.50
D161310 Western Elec. 50Kc to 4 Mc $2.00
352-7250-2A-15/16" dia.. 140 cy to 175 Kc ..$1.25
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GE 7557296-250 KVA ¼ microsecond $15.00

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ELECTRONICS

What to SEE at the 1949 Radio Engineering Show

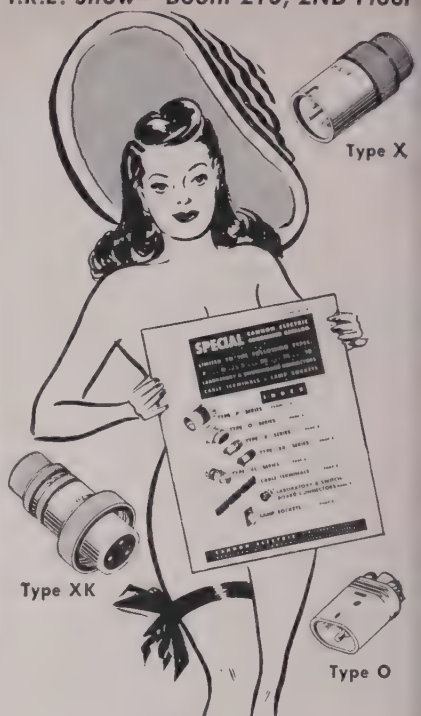
Directory of 200 Exhibits

(Continued from page 79A)

Firm	Booth
John F. Rider Publisher, Inc., New York, N. Y. Technical Literature and electronic equipment.	312
Sanborn Co., Cambridge, Mass. Galvanometer assemblies, photographic type oscillographs, single and multichannel direct-writing recorders and associated amplifiers.	S
Carl W. Schutter, Rockville Centre, N. Y. Radar Components, consisting of choke flanges, cover flanges, special flanges, rigid waveguide, brass and aluminum, adaptors, E & H Elbows.	269
Hermon Hosmer Scott, Inc., Cambridge, Mass. Dynamic Noise suppressors, Amplifiers, Sound Level Meters, Laboratory equipment.	V
Shallcross Mfg. Co., Collingdale, Pa. Instruments, Resistors, Switches.	281
Sherron Electronics Co., Brooklyn, N. Y. Multiwave shape generator, comparison oscilloscope, oscillo-synchroscope, electronic voltage regulated supply, RF cathode ray null detector.	C
Shure Brothers, Inc., Chicago, Ill. Microphones, phonograph pickup cartridges, phonograph pickups, wire recording heads, tape recording heads, microphone accessories.	264
Sigma Instruments, Inc., Boston, Mass. Sensitive relays for AC and DC., polarized relays for general applications and for high speed keying such as in teletype applications.	209
Simpson Electric Co., Chicago, Ill. Electrical Indicating Instrument, and radio test equipment.	86
Smith Paper, Inc., Lee, Mass. Metallized Condenser Paper, Kraft and Hemp Condenser, Kraft and Benares Electrolytic papers, coil and tan papers.	M
Sola Electric Co., Chicago, Ill. Sola Constant Voltage transformers.	21
Solar Mfg. Corp., North Bergen, N. J. Electrolytic Capacitors, various types of paper capacitors, including metallized paper types, radio noise filters and capacitor analyzer.	101
Somerset Labs., Inc., Union City, N. J. Noise suppressing preamplifier for use in record reproducing systems including models for all uses. Amplifier for music reproduction incorporating dynamic noise suppression.	E
Sorensen & Co., Inc., Stamford, Conn. AC line voltage regulators, nobatrons, 400 cycle regulator.	14
Sperry Gyroscope Co., Div., The Sperry Corp., Great Neck, N. Y. Microwave Measuring Instruments, Klystron tubes.	18–20
Sprague Electric Co., North Adams, Mass. Ceramic, Electrolytic, Mica and Paper Dielectric Capacitors, Fixed Wire Wound Resistors, Filters, high voltage networks.	57 & 58
Standard Piezo Co., Carlisle, Pa. Quartz crystal and frequency control units.	310
Standard Transformer Corp., Chicago, Ill. Transformers, Reactors, Power Packs, Transmitters.	263
Star Expansion Products Co., New York, N. Y. Electronic accessories, (Star miniature tube pin straighteners and Star miniature socket wiring plugs), precision die castings, toggle bolts.	P
Stoddart Aircraft Radio Co., Detroit, Mich. Noise and Field intensity Meter and Radiation Monitor.	56

(Continued on page 81A)

See Cannon Electric Exhibit at I.R.E. Show—Booth 210, 2ND Floor



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★ **THE RJC-2 SPECIAL CANNON ELECTRIC** Condensed Catalog covers the electrical connectors sold through our 300-odd regular radio parts distributors for radio and sound applications such as microphones, amplifiers, transmitters, receivers, etc. They include type series "P", "X", "XK" "XL", "TQ". Also shown in the same catalog are Sectional Cable Terminals, Laboratory & Switchboard Connectors and Bayonet Type Lamp Sockets. List prices are given on all items. Address Dept. B-377 for your free copy.

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What to SEE at the 1949 Radio Engineering Show

Directory of 200 Exhibits

(Continued from page 80A)

Firm	Booth
Super Electric Products Corp., Jersey City, N. J. Complete line of AM, FM and TV Coils, IF, RF Chokes, Transformers, etc., in both Audio and Radio Frequency.	Z
Superior Electric Co., Bristol, Conn. New low Capacity Stabiline voltage regulators, new stabiline voltage regulators. Powerstat Variable transformers.	108–110
Surprenant Mfg. Co., Boston, Mass. Television Line Cable, Special Coaxial Cable, Antifungus Wire, insulation, plastics.	38
Sylvania Electric Prod., Inc., New York, N. Y. Germanium Diodes, Germanium Triodes, Cathode Ray Tubes, Microwave Equipment, Radio Receiving Tubes, Radio Tube Parts.	104–106
Synthane Corp., Oaks, Pa. Laminated Plastic Products, Sheets, Rods, Tubes, Molded Laminated, Molded macerated, fabricated parts.	Q
Tech Laboratories, Inc., Palisades Park, N. J. Attenuators, variable and fixes, precision attenuators, potentiometers, Mixers, Switches, audio, rf and midget, silver soldering pot.	206
Technology Inst. Corp., Waltham, Mass. Precision, linear and functional potentiometers, audio Z-Angle Meter, R-F Z Angle Meter, R-F Power Oscillator, Phase-Angle Meter.	N
Tektronix, Inc., Portland, Ore. Three types of wide band oscilloscopes, two types of square wave generators.	238
Tel-Instrument Co., Inc., E. Rutherford, N. J. Type 1000 Teladapter, Type 1200 R-F-Sweep Generator, Type 1900 Multi-Frequency Generator, Type 2000 Bar and Dot Generator.	T
Tele-Tech, New York, N. Y. Magazines.	286
Terminal Radio Corp., New York, N. Y. High Quality Sound Equipment, Test Equipment, Miscellaneous radio parts.	287
Test Equipment Sales, Philadelphia, Pa. Test Equipment.	216A
Times Facsimile Corp., New York, N. Y. Facsimile Communications equipment, tuning fork controlled frequency standards, tube clamps	23 & 24
Tracerlab, Inc., Boston, Mass. Equipment for radioactivity research and for radiation health protection, including the Autoscaler, The "64" Scaler, Automatic Sample Changer.	332
Transvision, Inc., New Rochelle, N. Y. Receiver kits combining television, FM and AM, Sweep Signal Generators, Field Strength Meter. Booster, Antennas.	203 & 204
Truscon Steel Co., Youngstown, Ohio Technical information on selfsupporting and Uniform Cross-Section Guyed Radio Towers, Copper Mesh Ground Screen.	202
United Electronics Co., Newark, N. J. High Vacuum Transmitting tubes, gas rectifiers and thyratrons, vacuum capacitors.	249
U. S. Air Force, Washington, D. C. A 60′ exhibit depicting the work of Air Force Air Communications.	3rd floor
U. S. Army Signal Corp. exhibit.	3rd Floor
U. S. Navy Electronic exhibit.	3rd Floor
United Transformer Co., New York, N. Y. Transformers, reactors, chokes, voltage regulators, filters (audio, carrier, supersonic) high Q coils, filter coils, stepdown transformers, equalizers.	81

(Continued on page 83A)

NEY PRECIOUS METALS *in* INDUSTRY

PALINEY #7 CONTACTS IMPROVE PRECISION POTENTIOMETERS

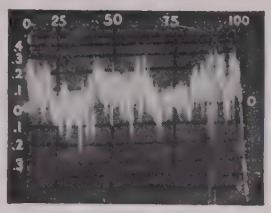

FIGURE 1. Cathode Ray oscillograph showing percentage error of standard potentiometer after one million cycles or two million sweeps of phosphor bronze contact over the wire. Initial linearity was — .17% and the error increased to ± .28% plus noise.

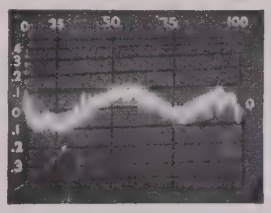

FIGURE 2. Shows performance of modified potentiometer after one million cycles or two million sweeps of PALINEY #7 contact over wire. The initial error was reduced to ± .12% and this linearity was maintained throughout the test.

RESULTS OF LIFE TESTS on nickel-chrome wire-wound potentiometers using contacts of PALINEY #7 in comparison with phosphor bronze.

Tests were made on a potentiometer equipped with a phosphor bronze contact in comparison with the same type potentiometer with a PALINEY #7 precious metal contact. Error measurements were made on a special tester equipped with cathode ray tube calibrated to measure directly in percentage of error.

Other important Ney Precious Metal Products for industry include NEY-ORO #28, a special alloy developed for contact brushes against coin silver slip rings . . . gold solders . . . fine resistance wires (bare or enameled) and a wide range of other alloys having many specialized applications.

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ASSOCIATED TECHNICAL BOOKS: "Television Receiving Equipment" (2nd Edition), by W. T. Cocking, M.I.E.E. One of the most important British books on television, 13 shillings ($2.60): "Wireless Direction Finding" (4th Edition), by R. Keen, B.Eng. (Hons.), A.M.I.E.E. An up-to-date and comprehensive work on the subject, 45 shillings ($9.25); available from the British address above.

What to SEE at the 1949 Radio Engineering Show

Directory of 200 Exhibits

(Continued from page 81A)

Firm	Booth
VEE-DX, Unionville, Conn. Television Antennas, Masts, Towers and accessories.	306
Veterans Administration Demonstration of disabeled veterans working ability.	248A
Victoreen Instrument Co., Cleveland, Ohio Instrumentation in Nuclear Physics.	328 & 329
Video Television, Inc., New York, N. Y. Television Antennas.	274A
Vision Research Lab., Inc., Richmond Hill, N. Y. Vision Front End, Model 701, Vision Tele-Boosters, Model TVA, TVX TVL—The FM TeleTuner, Test equipment, tele-marker.	218
Waldes Kohinoor, Inc., Long Island City, N. Y. Truarc Retaining Rings.	230
Waterman Products Co., Inc., Philadelphia, Pa. Portable oscilloscopes, as well as regular type, together with associated equipment. Rayonic cathode ray tubes will also be exhibited.	216
Webster-Chicago Corp., Chicago, Ill. Automatic Record Changers, Wire Recorders.	256
Webster Electric Co., Racine, Wis. Pickup cartridges and tone arms for LP playing equipment, magnetic cartridges, retractable cartridges, standard cartridges.	290
Welwyn Electronic Components, Inc., New York, N. Y. High stability carbon resistors, miniature wirewound resistors, pyromatic resistors, vitreous enameled resistors.	89
Western Lithograph Co., Los Angeles, Calif. E-Z Code Wire Markers, Business Systems, Cable, Conduit and Pipe Markers, High Production Identification Methods.	107
Westinghouse Electric Corp., Pittsburgh, Pa. Point-to-point radio, oil insulated selenium rectifiers, tubes, transformers, instruments and oomphometer, cores, magnetic comparator, circuit breakers, contactors.	62–69
Weston Elec'l. Inst. Corp., Newark, N. J. Electronic and radio service instruments.	282 & 283
S. S. White Dental Mfg. Co., New York, N. Y. Flexible shafts and resistors.	251
Wind Turbine Co., West Chester, Pa. A tower section and a VHF Antenna.	42
Workshop Associates, Newton Highlands, Mass. High frequency antennas.	39

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

New Shock and Vibration Control Material

A new, all-metal resilient material providing dual protection against shock and vibration has been developed by **Vibrashock,** of **Robinson Aviation, Inc.,** Teterboro Air Terminal, Teterboro, N. J.

Described by the manufacturer as "Met-L-Flex" mounting systems, this type of isolation offers uniform performance under temperature extremes; is less subject to permanent set; permits wide loading range; inter-wire friction providing

(Continued on page 84A)

"Wow-Meter"

Newly developed direct-reading instrument simplifies measurements of variations in speed of phonograph turntables, wire recorders, motion picture projectors and similar recording or reproducing mechanisms.

The Furst Model 115-R "Wow-Meter" is suitable for both laboratory and production application and eliminates complex test set-ups.

A switch on the front of the panel permits selection of low frequency cut-off and corresponding meter damping for use on slow speed turntables.

Frequency Response: ½ to 120 cycles or 10 to 120 cycles

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New Possibilities In AF ANALYSIS

with Model AP-1 PANORAMIC SONIC ANALYZER

- Indications are spectrographic-frequency versus voltage
- Quick overall views of the 40-20,000 cps spectrum are provided once per second
- Tedious, point by point frequency checks are eliminated
- Observations of random changes in energy distribution are possible
- Chances of missing components are removed
- Operation is simple
- Voltage amplitude ratios as high as 1000 :1 are measureable

Model AP-1 assures faster, simpler audio analysis by *automatically* separating the components of complex audio waves and *simultaneously* measuring their frequency and amplitude.

Whether your problem is investigation of harmonics, intermodulation, transmission characteristics, high frequency vibration, noise or acoustics, it will pay to look into the unusual advantages offered by the Panoramic Sonic Analyzer.

Write NOW for complete technical data, price and delivery.

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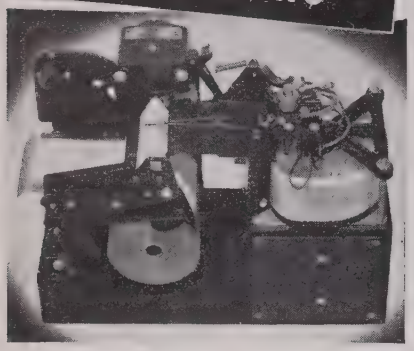


Galvanometer available separately if desired

PERMANENT Records
•
NO INK
•
RECTILINEAR Writing
•
RUGGED Construction with EXTREMELY HIGH torque movement (200,000 dyne cms for 1 cm deflection)

While designed primarily for use in the Sanborn direct-writing electrocardiograph (the Viso-Cardiette) this assembly (or the galvanometer alone, if desired) has sufficient potential value for varied industrial applications to warrant this announcement of availability for non-medical uses.

The complete unit illustrated comprises the galvanometer and writing arm, with associated paper drive (No. 572M – 500). The galvanometer and writing arm are available as a separate unit (No. 572M – 300). Recording styli available in two types; fine line writing approximately 1/3 mm; wide line writing approximately 1 mm. Recording paper can be furnished in 200 ft rolls, 6 cm wide (No. 572-737-P3).

TABLE OF CONSTANTS

Sensitivity	10 ma/1 cm.
Coil resistance	3,000 ohms, center tapped for push-pull operation.
Critical damping resistance	500 ohms.
Undamped fundamental frequency	45 cycles/sec.
Stylus heater requires from external source	1.25 volts, 3.5 amps, AC or DC
Maximum undistorted deflection	2.5 cm. each way from center
Marker requires from external source	1.25 volts, at 1.5 amps, AC or DC
Paper speed	25 mm/sec.
Chart ruling	1 mm intervals

In the development stage are other Sanborn "medical recording" instruments which have apparent industrial applications. These include an Electromanometer for direct measurement of "pressures", and several models of multi-channel (2 to 6) recorders, both direct recording and photographic.

Visit Booth S at I.R.E. Convention for demonstration, or write for descriptive bulletin

INDUSTRIAL DIVISION
SANBORN COMPANY
39 Osborn St.
Cambridge 39, Massachusetts

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 81A)

inherent high damping action; resistance to aging or deterioration; nonlinear load-deflection characteristics providing shock protection as well as vibration isolation.

This company now has available complete mounting bases, ready for installation of equipment. These may be procured in standard form factors, or by custom fabrication conforming to Government performance specifications. Detailed information supplied on request.

New Enterprise

An established English firm, Welwyn Electrical Laboratories, Ltd., has recently opened a New York office.

Operating in this country as **Welwyn Electronic Components, Inc.,** 234 E. 46 St., New York 17, N. Y., this firm specializes in solving difficult resistor and capacitor problems.

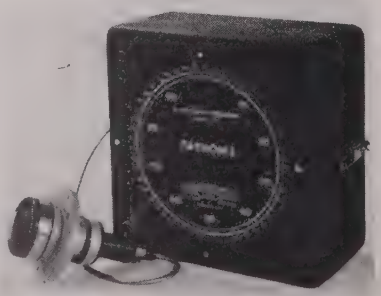
Welwyn high-stability carbon resistors are made in 1% tolerance from 100 ohms to 10^4 ohms. Claimed by the manufacturer to be individually noise tested before shipment, these resistors are outstanding for their quietness of operation in high-gain audio and nucleonic applications as they approach wirewound resistors in noise-free operation. The reactive component is nil to frequencies above the supersonic. In low-resistance values, they can be supplied in nonreactive form for operation at frequencies of 100 mc.

Above 10^4 ohms and up to 10^9 ohms, they supply a pyromatic resistor with proportionate high resistance values.

In wire-wound types, this firm produces vitreous-enamelled and cement-coated power resistors. Outstanding is a 3-watt vitreous resistor capable of full dissipation, but of miniscule physical size.

The aforementioned is completely described in Welwyn's latest catalog, available to firms requesting it on their corporate stationery.

Recent Catalogs



Kaar Engineering Co., Middlefield Road, Palo Alto, Calif. have announced literature descriptive of their Electronic Echo Depth Sounder. Interesting to the owner of small fishing fleets and yachts, it will operate over depths of 100 or more fathoms. Of small physical size, with only two units to install and low power drain, it works on ultrasonic principles.

(Continued on page 85A)

THE TEKTRONIX TWOSOME

Tektronix Type 511-A Oscilloscope
$795 f.o.b. Portland

NEED WIDE BAND AND FAST SWEEPS?

The Type 511-A, with its 10 mc. amplifier and sweeps as fast as .1 microsec./cm. is excellent for the observation of pulses and high speed transient phenomena. Sweeps as slow as .01 sec./cm. enable the 511-A to perform superlatively as a conventional oscilloscope.

Tektronix Type 512 Oscilloscope
$950 f.o.b. Portland

NEED DC COUPLED AMPLIFIERS AND SLOW SWEEPS?

The Type 512 with a sensitivity of 7.5 mv./cm. DC and sweeps as slow as .3 sec./cm. solves many problems confronting workers in the fields where comparatively slow phenomena must be observed. Vertical amplifier bandwidth of 1 mc. and sweeps as fast as 3 microsec./cm. make it an excellent general purpose oscilloscope as well.

BOTH INSTRUMENTS FEATURE:

- *Direct reading sweep speed dials.*
- *Single, triggered or recurrent sweeps.*
- *Amplitude calibration facilities.*
- *All DC voltages electronically regulated.*
- *Any 20% of normal sweep may be expanded 5 times.*

Phone EA 6197 — Cable Tektronix

TEKTRONIX INC.

712 S. E. Hawthorne Blvd.
Portland 14, Oregon

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 84A)

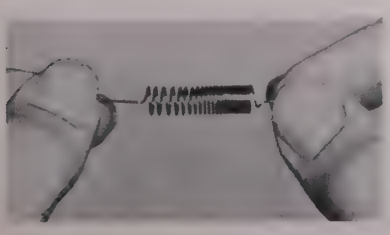
A New Aspect of Precision Instrumentation

The National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C. has announced a new technique in transducers, for translating minute displacements of motion into variations of resistance, voltage, or current. Still under development, it has already been perfected to a point where laboratory engineers will find the process worth while to investigate.

Operating on the change of resistance principle, from a coiled or distended spring, the technique lends itself to bridge constructions so that the change in output, electrically, from mechanical displacement, is double the applied voltage, as one set of arms of the bridge is increased while the second set is decreased, in their respective conductivity.

Springs are coiled of nickel-alloy wire, gold-plated to a thickness of 1/10 mil. When in their rest state, they offer the resistance of a cylindrical tube, but as tension increases the resistance changes to that of the linear wire itself. Thus displacements as small as 1 $Y10^{-6}$ are possible to translate into electrical currents and are indicated upon a galvanometer scale.

When actuated by another transducer, such as a bi-metallic strip electrical outputs can be easily measured from small changes of temperature, etc. Then the technique lends itself to accelerometers, pressure indicating elements, strain gauges, electric weighing devices, voltage regulators, dc to ac inverters, and many other applications.



Shown is a spring, partially stretched, and also a bridge element for electrically

(Continued on page 86A)

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THE LOWEST EVER CAPACITANCE OR ATTENUATION

We are specially organised to handle direct enquiries from overseas and can give

IMMEDIATE DELIVERIES FOR U.S.A.

Billed in Dollars. Settlement by your check. Transaction *as simple as any local buy.*

LOW ATTEN TYPES	IMPED OHMS	ATTEN db/100ft at 100 Mc/s.	LOADING ft per Mc/s.	O.D."
A 1	74	1.7	0.11	0.36
A 2	74	1.3	0.24	0.44
A 34	73	0.6	1.5	0.88

HIGH POWER FLEXIBLE

LOW CAPAC TYPES	CAPAC mmf/ft.	IMPED OHMS	ATTEN db/100ft 100 Mc/s.	O.D."
C 1	7.3	150	2.5	0.36
PC 1	10.2	132	3.1	0.36
C11	6.3	173	3.2	0.36
C 2	6.3	171	2.15	0.44
C22	5.5	184	2.8	0.44
C 3	5.4	197	1.9	0.64
C33	4.8	220	2.4	0.64
C44	4.1	252	2.1	1.03

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V.L.C. ★

★ Very Low Capacitance cable

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CONTRACTORS TO H.M. GOVERNMENT
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CABLES: TRANSRAD, LONDON.

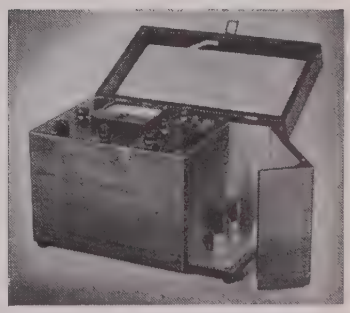
S·S·White MOLDED RESISTORS

The "All-Weather" Resistors

ARE USED IN THIS SUPER-SENSITIVE ULTROHMETER

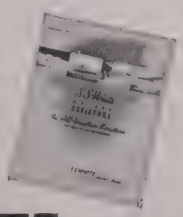
An S.S.White 100 Megohm Resistor is used as the plate load resistor for the first tube in the D.C. amplifier in this instrument which measures very small d.c. currents and voltages over an extreme range of values. The manufacturer, Beckman Instruments Division of National Technical Laboratories, says of the S.S.White Resistor "it has been very satisfactory"—which checks with the experience of many other electronic equipment manufacturers who use S.S.White Resistors.

Photo courtesy of National Technical Laboratories, So. Pasadena, Calif.



WRITE FOR BULLETIN 4505

It gives essential data about S.S.White Resistors including construction, characteristics, dimensions, etc. Copy with price list on request.



S.S.WHITE RESISTORS

are of particular interest to all who need resistors with inherent *low noise level* and *good stability* in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS

STANDARD RANGE
1000 OHMS to 9 MEGOHMS

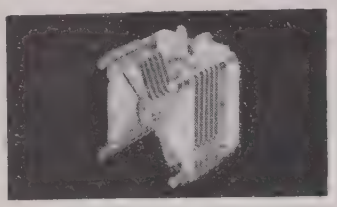
S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO. — DEPT. GR, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AND ACCESSORIES
MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

New! **JOHNSON**

TYPE L VARIABLES

CERAMIC SOLDERED
FOR STABILITY-STRENGTH



BUTTERFLY TYPE

Available in Three Models:

2.8 to 10.5 mmf, 4.3 to 26 mmf, 6.5 to 51 mmf.

Spacing .030" and .080"

Two sets of stator contacts are provided for connecting components to either side of the variable without appreciably increasing lead inductance of the circuit.

JOHNSON also makes Type L Variables in Single, Dual and Differential types in many different models.

All are ceramic soldered. There is nothing to work loose causing stator wobble and fluctuations in capacities.

Available in .030" and .080" spacings for all types of communications equipment having tuned circuits operating as high as several hundred megacycles.

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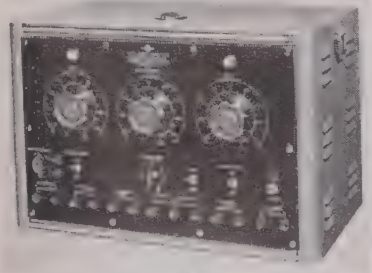
SEE THE "BOOTH" POWER SUPPLY UNITS IN BOOTHS 297-298



The Model 500SV is a power type 2 Circuit POWER SUPPLY, providing smoothly adjustable AC & DC POWER from 2 CIRCUITS, separately controlled & electrically isolated. The output from each circuit can be increased or decreased by simply turning a knob.

INPUT REQUIREMENTS—115V, 1ø, 50/60 ~, max. power input 770VA.

CIRCUIT #1—WITH VERNIER CONTROL

AC Output—0-10 Amps. with max. of 8 Volts; 0-30/75/150/300/600/750 Volts with max. of 200MA.

DC Output—0-20/50/125/250/500/750 Volts with max. of 175MA. Ripple less than ¼ of 1%.

CIRCUIT #2

AC Output—0-10 Amps. with max. of 10 Volts; 0-135 Volts with max. of 3 Amps., convenient 115V constant potential terminals supplied directly from input circuit.

DC Output—0-10 Amps. with max. of 3 Volts. Ripple less than 5%.

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ELECTRO-TECH EQUIPMENT CO., INC
117 LAFAYETTE ST., NEW YORK CITY
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—INSTRUMENT SPECIALISTS—

NEWS—NEW PRODUCTS

The manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from 85A)

indicating small mechanical displacements. Still under development, this description is being published to appraise our readers of the strides taking place within the industry itself, for more precise mensuration techniques.

Beat Frequency Oscillator

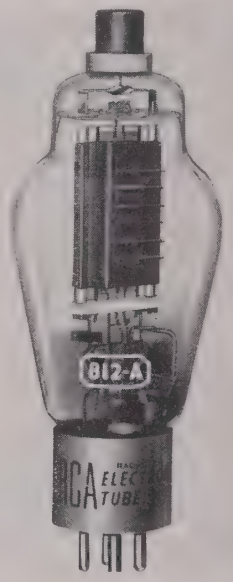
General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass., has announced the post-war redesign of their familiar 913-A beat-frequency oscillator, now known as Type 1304-A. The same range is covered with many improvements added. Calibration is now done at line power frequency, through the means of a neon-lamp indicator.

The new gear-driven illuminated logarithmic dial, with improved bearings for alignment accuracy, improves the application use of the instrument. A decremeter adjustment of ±50 cps allows for accurate readings to be made at any point along the entire frequency range of 20 to 20,000 cps. High output at low distortion, 0.3 watt at less than 0.25% across the 600-ohm terminals is the maker's rating, although as much as 1 watt can be obtained from the instrument at 1% distortion. Drift is less than 7 cps, most of which occurs in the first hour of operation, with stability achieved after about two hours of use. Relay-rack and table models are both available.

Three RCA Improvements

The RCA-812A power triode (superseding the 812) features a zirconium-coated plate having radiating fins to give greater dissipation capability, grid and plate leads designed to have low rf loss, and a strengthened top-cap assembly with ceramic collar.

Because of its high perveance, the 812A can be operated at high efficiency and low driving power. For example, a pair of 812A's under ICAS conditions in unmodulated class-C service can be operated with a plate input of 520 watts and the low driving power of 13 watts. Operation with maximum ratings is permissible up to 30 Mc, and with reduced ratings to 100 Mc.



The RCA-672-A mercury-vapor thyratron, which supersedes the 672, has the following modifications: (1) heater current is reduced from 6 to 5 amperes, (2) maximum peak forward and inverse anode voltage ratings are increased from 1500 to 2500 volts, (3) maximum peak anode current is increased from 30 to 40 amperes, (4) maximum average anode current is increased from 2.5 to 3.2 amperes.

The RCA-4×500A power tetrode is radiator-cooled, and is intended for vhf operation as a power amplifier and oscillator. The maximum plate dissipation is 500 watts.

Small in size, the 4×500A features low-inductance leads, low grid-plate capacitance, effective shielding between grid

(Continued on page 87A)

Write for further details

"NOBLELOY" METAL FILM PRECISION RESISTORS

★ GENUINE METAL FILM
★ NOT CARBON
★ NOTHING TO BURN
★ CLOSE TOLERANCES ½%, 1%
★ REASONABLE PRICES

The "NOBLELOY" X Type Resistors has proven itself over a period of 5 years in thousands of critical electronic circuits. Values and tolerances, ½ ohm to 30 megohms 1%; ¼ ohm to 200,000 ohms, ½%. Sizes, ½ to 5 watt.

CONTINENTAL CARBON, INC. CLEVELAND 11, OHIO

NEWS—NEW PRODUCTS

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 86A)

and plate circuits, and a grid terminal located at the center of the filament end of the tube to facilitate its use in coaxial circuits.

Technical bulletins with detailed information will be supplied on request to the **Tube Dept., Radio Corporation of American,** Harrison, N. J.

Plant Expansions

ALLENTOWN, Pa., witnessed the opening in October of a new manufacturing plant by the **Western Electric Co.** where precision electronic products are made by a staff expected to reach 2500 employees. WE has built a factory as modern as the electronic art itself, where quality will be the watchword of the production staff. A controlled-conditions plant, every precaution has been taken to insure cleanliness and dust-free atmosphere, as these are prerequisites in the manufacturing of small vacuum tubes, a large part of the output from this new factory in the Lehigh Valley.

CHICAGO, Ill., is the locus of the new plant of *Lectrohm, Inc.*, long-time maker of vitreous-enameled resistors and electrically heated soldering pots. In the rapidly expanding Clearing Industrial District of Chicago, the new address for Lectrohm is 5939 Archer Ave., Chicago 38, Ill. These new and larger quarters will speed production and delivery of the products of this company long active in the radio and electric fields.

NEW YORK, N. Y., has just been selected for the new *Fairchild Recording Equipment Corporation*, with offices at 30 Rockefeller Plaza, and the locus of a new manufacturing plant yet to be decided upon, but probably in the Long Island City vicinity. This new enterprise has been formed to take over the sale of the disk recording equipment of the Fairchild Camera & Instrument Corporation, and also to market a new professional-quality studio-type magnetic-tape recording and playback device, which was developed by Dr. D. G. C. Hare, recently president of the Deering-Milliken Research Trust, who is serving as a consultant to the new firm. Other audio items will shortly find their way into the new Fairchild line, too.

TOLEDO, Ohio, recently saw the expansion of the *Kimble Glass Co.* plant, where direct-viewing television glass bulbs are made in quantity by automatic machinery. The rapid expansion of the interest in television has caused a continuing shortage of glass envelopes for the cathode-ray tubes used for picture reproduction, and the Kimble organization have increased their production capacity tremendously by this rapid conversion from handmade envelopes to machine-fabricated units, with progress once estimated to take years condensed into a few months. Kimble is a division of Owens-Illinois Glass Company.

(Continued on page 88A)

SMALL ELECTRONICS PARTS

Grid Supports, filaments, anodes, plates, diodes, pigtails, lead wire hooks—closely machined parts for clystron and magnotron tubes and other electronic applications to your specification.

Complete line of oxy-gas-air burners and equipment.

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INCANDESCENT LAMPS
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Production or Laboratory Basis

Manufacturers contemplating New Plants or Plant Changes are invited to consult with us.

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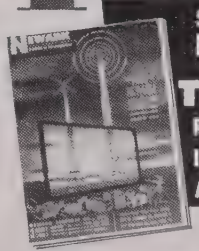

the 1949

NEWARK CATALOG

148 pages...20,000 items! Packed with pictures, charts, vital information!

No matter how tiny the part... how tremendous the system, it's listed in this mammoth catalog of standard brand equipment. The one easy, satisfactory way to always get reliable, dependable, top-performing, top-value equipment! A cannot-do-without for pros, hams, hobbyists, novices, old-timers, anyone, everyone, interested in TV or Radio!

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Please send me FREE Newark Catalog

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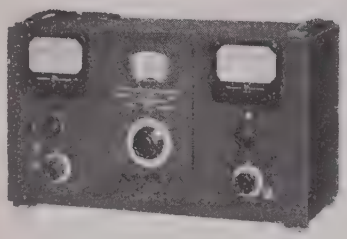
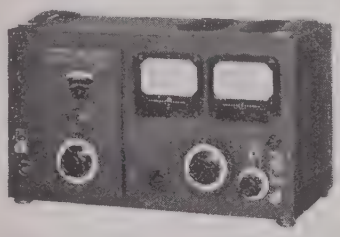
Laboratory Standards



STANDARD SIGNAL GENERATOR

Frequency range: 75 kc. to 30 mc. Output 0.1 microvolt to 2.2 volts.

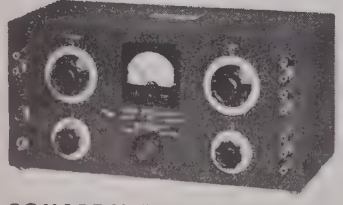
MODEL 65B



STANDARD SIGNAL GENERATOR

Frequency range: 2 mc. to 400 mc. Output 0.1 microvolt to 0.1 volt.

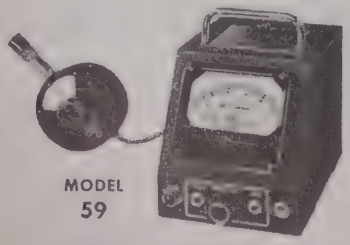
MODEL 80



SQUARE WAVE GENERATOR

5 to 100,000 cycles. Recommended for AM, FM and television testing.

MODEL 71



MODEL 59

MEGACYCLE METER

A versatile grid-dip oscillator covering the frequency range of 2.2 mc. to 400 mc.

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

CIRCULARS ON REQUEST

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

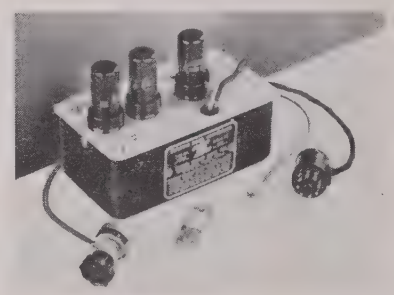
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 88A)

DOVER, N. H., welcomes the move from Brooklyn, N. Y. of *Clarostat Mfg. Co.*, one of the oldest makers of volume controls and resistance devices in the radio industry. The new plant was opened in November, affording over ¼ million square feet of space for offices, manufacturing and warehouse facilities, under one roof in a five-story building. For over a quarter century in Brooklyn, the move to New England is a departure for this firm, designed to increase operational efficiency by combining the several plants into which Clarostat was forced when expanding to meet with the increase in business that the past war brought to them.

Recent Catalogs



Herman Hosmer Scott, Inc., 385 Putnam Ave., Cambridge, Mass., announce literature describing their "Little-Wonder" type 110-A dynamic noise suppressor. Small physical size and remote mounting of the control from the chassis contribute to ease of installation of the unit in existing phonographs. Possessing noise-suppressing features superior to the frequency range of most current recordings, this unit includes a matched crystal pickup, for installation when it is used. Packaged units of this type lend themselves to easy merchandising of apparatus currently in popular favor.

Amplifier Corp. of America. 398 Broadway, New York 13, N. Y. have announced descriptive literature detailing their newest magnetic-tape recording equipment. This unit incorporated a twin recording track, on one tape, with instantaneous magnetically controlled reverse for continuous operation. This is similar to the shuttling of a typewriter ribbon. Mounted in separate cases for ease in carrying, the unit dovetails together when in operation, and includes storage space for microphone, connecting cables, and reels of tape.

(Continued on page 89A)

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In all shapes and forms for particular needs . . . including Wire, Sheet, Foil, Ribbon and Solders.

REFINING

Precious metals scrap reprocessed or purchased.

FINE WIRE and RIBBON

Made to exact specifications. All metals and alloys manufactured into wire and ribbon of very fine dimensions.

A New Instrument FOR INDUSTRIAL USERS OF PRECIOUS METALS

The SECON *Precious Metals* WEIGHT CALCULATOR

This instrument will rapidly calculate the weight of precious metals in the forms of Sheet, Wire, Tubing, and Circles. Write for details.

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 88A)

High-Fidelity FM Tape Recorder

Described as having been "designed expressly to the highest requirements of FM broadcast application," the Ampex Tape Recorder with a 35-minute transcribing capacity at 30 inches of tape per second is being marketed by **Ampex Electric Corp.,** 131 Howard Ave., San Carlos, Calif.

Frequency response is within ±1 db between 30 and 15,000 cps. Over-all distortion is 4% intermodulation at peak meter reading. At 10 db above peak meter reading the total rms harmonic distortion does not exceed 5%. Unweighted noise level is 60 db below 5% harmonic distortion for the system as a whole—including both amplifiers, bias, erase, and stray pick-up. Accuracy of playback timing is ±0.2%.

This recorder has separate heads for erase, record, and playback; separate record and playback amplifiers; a marking device for spotting tape when editing; relay and pushbutton controls for remote operation; forward and rewind speeds of over 300 in sec; and head gaps aligned to permit interchangeability of tapes without high-frequency loss.

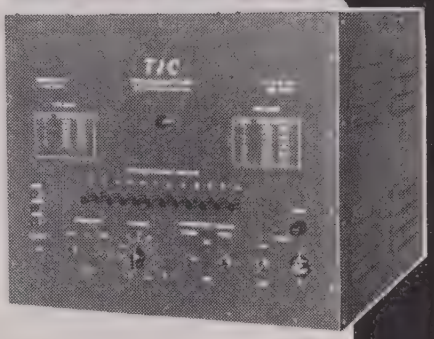
Recent Catalogs

• • •Application notes concerning "Adjustment of Filament Voltage of RCA-1B3-GT by Observation of Filament Temperature," AN-134; "Single-Section Filament Operation of Types 3S4 and 3V4," AN-135; "Overload Protection for the Horizontal Deflection Circuit in Television Receivers," AN-136; "Reduction in Peak Inverse Voltage Rating of Type 1B3-GT," AN-137, all by **Tube Department, RCA,** Harrison, N. J. In requesting these bulletins, specify the identifying code letters and numbers immediately following captions.

(Continued on page 90A)

Developed by TEL INSTRUMENT FOR THE TELEVISION INDUSTRY

New Type 12 CHANNEL R.F. SWEEP GENERATOR



- Instant Channel Selection by Push Button
- Rated for Continuous Service
- Pulse Type Markers at picture and sound carrier frequencies. Either or Both May be Turned On or Off.

No spurious markers produced. Accuracy 0.02% Xtal controlled.

Precision Wobbulator for television production line. 15 M.C. band width on all channels. Output is oscillator fundamental frequency. Zero signal output reference baseline always present. Output 1 v. across 75 ohms. Attenuator range 60 Db. Monitor signal provided.

PRICE $1330 F.O.B. E. RUTHERFORD, N. J.

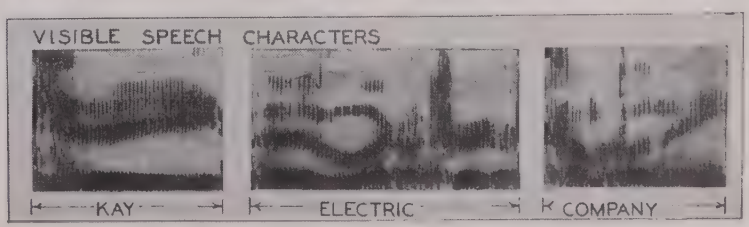
BOOTH "T" I.R.E. CONVENTION

Write for Full Data

Tel-Instrument Co. Inc.

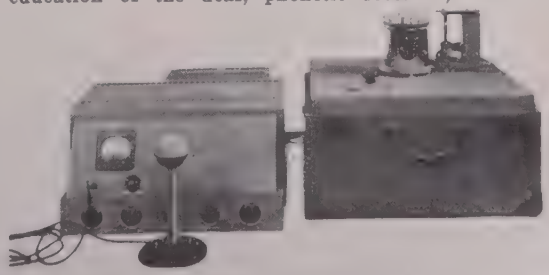
50 PATERSON AVENUE • EAST RUTHERFORD, N. J.

NOW . . . SOUND PATTERNS VISIBLY, PERMANENTLY RECORDED



Two records of speech or other complex waves available. One record plots energy level vs. frequency and time. Other record plots energy vs. frequency at any selected time.

The KAY SOUND SPECTROGRAPH may be used for general laboratory analysis of sounds and other complex waves. It is also useful for speech education of the deaf, phonetic research, instruction in foreign languages and other forms of training where VISIBLE SPEECH is required. Write for full details.



See Kay Spectragraph & other new instruments at Booth No. 22 I.R.E. Show

KAY ELECTRIC COMPANY

26 Maple Avenue Pine Brook, N.J.

MICRODIMENSIONAL WIRE & RIBBON

- Wires drawn bare to .0004" diameter
- Wollaston Process Wire .0005" to .000010"
- Ribbon rolled to .0001" thickness
- Made in almost all ductile metals and alloys; or we will draw wire from your own metals.

Your inquiry, with engineering specifications is invited.

SIGMUND COHN CORP.
44 GOLD ST. NEW YORK
SINCE 1901

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 89A)

High-Frequency Heating Unit

The new 2R Thermax Red Head, a high-frequency heating unit which has an output of 2.5 kw and will raise the temperature of $1\frac{2}{3}$ lbs of average general-purpose material from 80° to 250°F in one minute, reducing mold pressure as much as 80%, has been designed and produced by the **Thermex Div., Girdler Corp.**, Louisville, Ky.

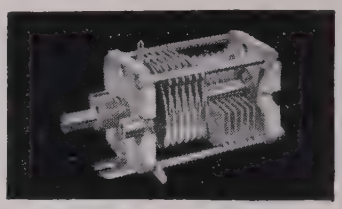
The standard lower electrode is a 10″×12″ aluminum plate. The upper electrode is 10″×12″ stainless steel wire mesh. Spacing between the electrodes is adjustable from $\frac{1}{4}$″ to 5″, and the drawer accepts preforms up to $4\frac{3}{4}$″ in thickness. It operates on 230 or 460 volts, 60 cps, three-phase power supply. Rated output requires 5.6 kva input at 90% power factor. One WL437 hf power oscillator and six 872A vapor rectifiers comprise the tube complement. Net weight, 800 lbs; height, 55″; depth, $27\frac{1}{4}$″; width, $17\frac{1}{4}$″.

Ultra-Short Pulse Generator

The Mega-Pulser, a new ultra-short pulse generator that provides a pulse with a spectrum which, the manufacturer claims, more than covers the present video-frequency range, is being marketed by the **Kay Electric Co.**, Pine Brook, N. J.

(Continued on page 91A)

New! JOHNSON
TYPE L VARIABLES
CERAMIC SOLDERED FOR STABILITY-STRENGTH



DUAL TYPE
Available in Three Models:
3.5 to 27 mmf, 4.6 to 51 mmf, 6.8 to 99 mmf.
Spacing .030" and .080"

These new JOHNSON Variables are ideal for use where peak efficiency is required under the most adverse conditions, such as portable-mobile operation.

JOHNSON also makes Type L Variables in Single, Differential and Butterfly types in many different models.

All are ceramic soldered. There is nothing to work loose causing stator wobble and fluctuations in capacities.

Write For New JOHNSON Type L Variable Catalog Today!

JOHNSON
a famous name in Radio
E. F. JOHNSON CO., WASECA, MINN.

AT THE I. R. E. SHOW

EXHIBITING...

- The GUEST TELEVISION Hotel Distribution System
- ITI Studio Monitors
- The MULTIVISION Antenna Distribution System

Visit Booth No. 285

INDUSTRIAL TELEVISION INC.
359 Lexington Avenue • Clifton, New Jersey
The Vision in Television

"TAB" THAT'S A BUY!

We BUY and SELL and TRADE as WELL!

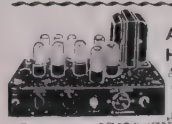
Send "TAB" Your Surplus Lists

TRANSFORMER TV POWER SUPPLY KITS No RF bursts!
Hi, Lo & Filam Voltages.
FEATURING Herm
Sld W.E. USN oil filled XFMR Inputs 105/115/125VAC 50-425 cps Outputs HiV & 600VCT or 300VDC/375MA & 6.3V/10A, 5V/8A, 2.5V/3A, 5V/3A. H.V. ins. exc for 630TS to 16" CR. 1000V & 300VDC & ALL Filaments Supply Kit. Above Xfmr & 2-3B24 Doubler-Rect & 5U4G rect. & ALL cndsrs, sockets, choke & data SPECIAL **$29.95**
5000V 300VDC & ALL Filaments KIT, Same Xfmr plus 5U4G & 3B24 rect., cndsrs, choke, sckts, data **$21.95**
Transformer Only **$16.95**

Basic TV & CRT PWR XFMR- 2.5 KV Xfmr out of BC412Scope with 2.5V/1.75A for 2 x 2 fil & 6.3V/.6A winding KENYON S13336 or Equiv ONLY **$8.95**
With 2 x 2 Tube & Safety Socket **$9.95**

TELEVISION SIGNAL BOOSTER
Sonar TELEBOOSTER Ultra-sens 13 CHANNEL Booster 3 tubes including 2-6J6's In Sharp Tuned Ckts. SELF-POWERED! Fine Walnut Case, COMPLETE .. **$14.50**

For Your Electronic Needs One Item or a Thousand
—SEE "TAB" FIRST—
Over 1,000,000 JAN Parts, Gov't tested & inspected. For Microwave, Industrial, Servicing and Amateur Needs . . .
BUY AT "TAB" and SAVE MONEY



AMPLIFIER KITS HIGH FIDELITY
A Hi-Fi circuit with perfect linear response, phase inverter & full tube complement featuring 2-2A3 PP output, 6SJ7&6SN7. All parts, tubes, controls, diagram & remarkable RCA Audio Amplif Chassis described beow. Less Output Xfmr. THIS IS A TRULY GREAT BUY AT **$14.95**
17.5-WATT AMPLIFIER KIT—Similar above with all major components except 2-1619/6L6 delivering 17.5 WATTS.
14-WATT AMPLIFIER KIT—Similiar above except 2-6V6GT delivering 14 Watts.
17.5 OR 14 WATT KIT—less output Xfmr, Only **$12.95**
RCA AUDIO AMPLIFIER CHASSIS—for AMPLIFIER KITS. Heavy duty Porcelainized chassis, Gray rustproofed 7¼ x 12¼ x 2¼". 9 Amphenol sockets incl 6 octal, 3 inpts, cutout for pwr transf & choke. Chassis marked for 2mic, Vol, Tone, Fuse, Tubes (7). Complete with 3FP triple section Electrolytics.

PRECISION RESISTORS
Write Qty Prices. We ship types in stock. 0.116 to 95000 ohms, Ea 30¢; 10 for ..$2.50
100000 to 950000 ohms. Each 40¢; 10 for 3.50

1 Meg	2.5 Meg	3.673 Meg	5 Meg	19.5 Meg
1.2	2.855	3.9.	9.05	20
1.5	3	4	10	
1.8		4.23	11.5	
2	3.5	4.5	12.83	

ABOVE SIZES EACH 75¢ ....TEN FOR $6.50
Vacuum Prec Resistors HiVolts—.12 .. .25
.6, .75, .83, .99, 1, 1.5, 2, 3, 3.75 megohms ½% accy SPECIAL $1; 10 for .....$ 7.50
Vacuum 12meg 10KV9W $1.35; 10/ 10.00
MVZ8/20W 30Meg25KV $1.98; 6/ 10.00
MFC105/1Meg ½%accy JANR29 1.98; 6 10.00
Type 2/20megJANR29/20KV½%accy 29.95
IRC ATTENUATORS-100000 ohms 20 pos 2.98
250000 ohms 20 position 4.98

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Image-Converter. The Famous Picture Tube that sees in the dark! HiSensitivity simplified design 2" dia., Willemite screen-Resolution up to 350 lines/in. Complete data & Tube, "TAB" SPECIAL ....$ 9.98

12DP7 GE MagnDefiTelev CR & Data SPECIAL $12.95, 2 for $25. 10 for 115.00
5FP7-5" CR Tube SPECIAL $1.49, 2/ .. 2.75
9LP7-9" CR Tube SPECIAL $2.69, 2/ 4.98
6L6 Metal RCA Kenrod SPECIAL ea. .89
10 for $8., 100 for 70.00
866A Tubes Sockets xfmr 5.95
872A Tubes Sockets xfmr 12.95
G.E. GL434A slm 7C29/1KW. HF RF 7.95
REL36 ACORN slm 6J4-rndGrid SPEC. .98

$3. Min. FOB N.Y.C. Add Post. & 25% deposit. Money back Guarantee. Return Mdse. Prepaid.

Dept. 2R, 6 Church St., New York 6, N.Y., U.S.A. WOrth 2-7230 **"TAB"**

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 90A)

Its features are: pulse width, 0.025, 0.05, 0.1, and 0.25 microsecond; pulse amplitude, 100 volts at 50 ohms impedance; pulse shape, flat-top pulses 0.05 microsecond and greater; pulse rise and fall time less than 0.01 microsecond.

It also triggers from an internally or externally provided pulse, and provides a positive or negative pulse. The output pulse is delayed approximately 0.25 microsecond to allow observation on an oscilloscope.

Heavy Duty Selenium Rectifier

The Type "H" rectifier with individual selenium elements, measuring $6\frac{1}{4}'' \times 7\frac{1}{4}''$ and rated at 12 amperes (single-phase bridge), is being manufactured by **International Rectifier Corp.**, 6809 S. Victoria Ave., Los Angeles 43, Calif.

Features incorporated in these assemblies are: (1) interlocking assemblies of rectifier components, (2) conservatively rated terminals, (3) special moisture proofing.

The manufacturer claims that the elements have stable characteristics. Leakage current is less than 1 ma/cm² at 25 volts rms in the reverse direction. The type "H" is especially suitable for all applications requiring output in access of 10 amperes.

Recent Catalogs

• • • A bulletin and an accompanying news release describing a chassis punch driven by screw action that cuts square or round holes to facilitate mounting angular parts on sheet metal, by **Pioneer Broach Co.**, 1424 S. Main St., Los Angeles 14, Calif.

(Continued on page 93A)

RAWSON Thermocouple Meters

No Wave Form Errors
R.M.S. Readings
½ of 1% Accuracy

SINGLE RANGES from 1 ma full scale to 10 amperes full scale. Good from DC to 2 megacycles and higher.

MULTIPLE RANGE INSTRUMENTS with selector switches. Any practical combination of voltage or current ranges furnished to order.

Example 1.5-5-15-50-150-1500 volts at 1000 ohms per volt. DC to 10 KC.

RAWSON THERMAL MULTIMETERS
Ranges on one meter—10 ma to 3 amps, 300 mv to 1000 volts.

Write for Bulletin 502

RAWSON ELECTRICAL INSTRUMENT COMPANY
118 Potter Street Cambridge, Mass.
Representatives
Chicago Los Angeles

ALFAX ELECTROSENSITIVE PAPER

Now available to laboratories, instrument manufacturers, and experimenters.

ALFAX ELECTROSENSITIVE PAPER—marks directly by electric impulse. Density varies directly with intensity of signal so recordings can be made self-calibrating by introducing standard signals of different intensities.

ALFAX ELECTROSENSITIVE PAPER—in helix type recorder will record signal the instant it occurs—without overshooting—no need for compensation or damping. IT IS INERTIA FREE.

ALFAX ELECTROSENSITIVE PAPER is extremely sensitive, so that the paper can be fed slowly, yet extremely rapid variations will be recorded in the helix stroke at writing speeds 300" or more per second.

ALFAX ELECTROSENSITIVE PAPER is ideal for recording a group of related signals without the problems of multiple pens and their maintenance. Recordings differentiate the transient or stray signals from the true signals. Sudden signals of unusual amplitude cannot damage the recorder nor result in false readings as in D'Arsonval movements and pen type movements.

ALFAX ENGINEERING includes making special papers or developing electronic circuits and electrode materials to emphasize any portion of wave form or signal. Recordings are easily interpreted even where noise to signal ratio is greater than one.

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Alfax Paper & Engineering Co.
40 Riverside Ave., Brockton, Mass.
Enclosed is one dollar for a roll of Alfax Electrosensitive paper for experimental purposes to be mailed postpaid with booklet, "Questions and Answers on Electro Sensitive Paper."
Name .....
Position .....
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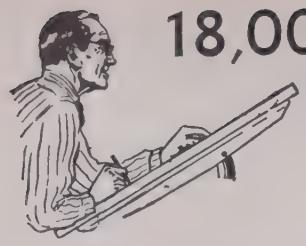
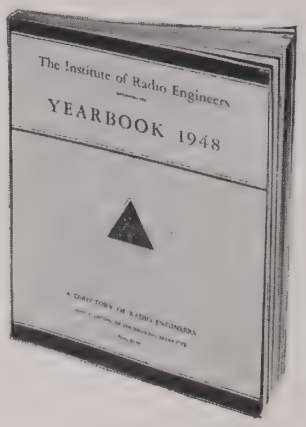


18,000 Radio Engineers use the IRE YEARBOOK and its Product Data



The 18,000 engineers, members of The Institute of Radio Engineers, receive and use this well bound, smythe sewn book, which is really three directories in one; (1) A Directory of IRE Engineers arranged both alphabetically and geographically, (2) A List of 3000 Supply Manufacturers, and (3) A Product Index to what they make.

Engineers like, and use the product classifications because they are based on fundamental grouping rather than terminology. Organized into 68 product groups and 9 non-manufacturing services, the engineer can find what he wants swiftly and easily. Yet, the information is complete, and a comprehensive picture of each firm's entire engineering line is given by codes for engineering products or services in the alphabetical index. Result — the IRE YEARBOOK is useful and well used by engineers.

4 Ways Advertisers Use the IRE YEARBOOK to Tell Their Story

1. Some firms place a complete 2, 4 or 8 page folder as a bound-in insert in the YEARBOOK. This "Catalog Plan" insures permanent filing of such literature where the engineer can always find it. This insert provides complete, working information right where and when it is sought by the most important design and production engineers of radio-and-electronics. You furnish 18,000 printed booklets (8½"x11") and we bind them in for $250. up to 4 pages, and $450. up to 8 pages. You get complete distribution to the cream of engineers in our field at *less cost than mailing.*

2. Manufacturers who have a large number of catalogs and data folders have taken an advertisement to list the "library of literature" available to engineers. Such ads contain illustrations of the catalogs, and usually an easy-ordering number system, or coupon. The IRE YEARBOOK provides the most logical place for doing this specific advertising job.

3. A "Complete Line" advertisement is the most widely used type in the IRE YEARBOOK. Last year 160 firms used "Complete Line" ads to present a comprehensive summary of *all their* products of interest to radio-and-electronic engineers. It is complete reference copy, rather than promotional — fact-packed, and useful.

4. "Single Item Presentation" usually a $60.00 1/6th page, or a $100.00 1/3rd page unit, spotted in a specific product classification is used, in some cases by firms who place no other advertising in our field. An interesting variation on this plan is the firm that places a number of small ads so that a single item appears in a specific product classification, such as transformers in the Transformer listings, and coils in the Coil class, etc. Bulk rates for the total amount of space used in the YEARBOOK make this "position spotted" service economical.

Service and timing account for the sales making power of ads in the YEARBOOK. One advertisement works for you for a full year, and provides the engineer your product facts exactly when he needs them — truly a business-winning selling-service.

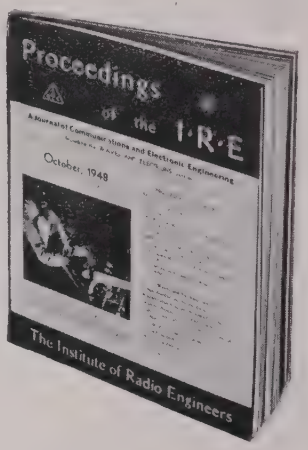
Just for comparison, the popular 2/3 page unit (always next to listings) costs only 1¢ per engineer's copy. The insert rate is less than mail distribution cost — yet reaches the finest engineering list to whom you could possibly send your literature.

YEARBOOK rates and sizes are same as for "Proceedings of the I.R.E."			Preprinted Inserts
	1 page 7" x 10"	$250.	8½" x 11", 40 to 70 lb.
	⅔ page 4⅝" x 10"	180.	2 or 4 pages $250.
	⅓ page 4⅝" x 4⅞"	100.	8 pages $450.
	Column 2¼" x 10"	100.	
	⅙ page 2¼" x 4⅞"	60.	2 page spread $250.

Forms Close March 15.

TO SELL THE RADIO INDUSTRY TELL THE RADIO ENGINEERS

KEY to selling in a technical industry is telling design and production engineers about your product. Do this economically, to the $3 billion radio-electronic industry by advertising in "Proceedings of the I.R.E."



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Pre-Specification Selling

Product promotion ads in the "Proceedings of the I.R.E." get your story across to design men in the vital pre-specification period. This is the design engineer's magazine — which authentically reports electronic research and development. Your ads in it sell when plans are being made. Tell the engineers who set specifications and you will win sales.

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LEE WILLSON
Pacific Coast Representative
412 West Sixth Street
Los Angeles 14, Calif.

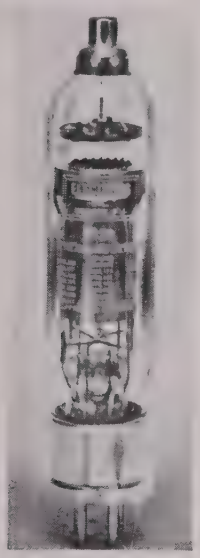
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 91A)

Grid Controlled Rectifier Tube

The new Type 5528 (C6L) a fast deionizing, temperature-free grid-controlled rectifier tube has been developed by **Electrons, Inc.,** 127 Sussex Ave., Newark, N. J.



Pertinent electrical characteristics of the type 5528 are: 60-second heating time; 500 volts peak inverse rating; 6.4 amperes steady dc; 77 amperes peak.

This tube is designed especially for high-power servomotor control or inverter applications which must operate at up to 800 cps. and where reliability and stable characteristics are required over wide ambient temperature ranges.

Inquiries should be directed to James H. Burnett at Electrons. Inc.

Recent Catalogs

• • •The FTL-10-A, a 23-voice-channel radio link system, especially advantageous where terrain conditions or water paths make wire installation costly or impossible; The FTL-11-A, an Fm uhf radio link, used to relay program material from the broadcast station to the transmitter, eliminating wire or cable circuits; the FTL-12A, a complete television broadcast transmitter monitor for AM and FM signals; the FTL-13A, an FM uhf broad-band radio link for multichannel telephone service; the FTL-15-A, an all-metal dummy antenna for FM broadcast transmitters which accurately measures and safely dissipates large amounts of vhf rf power by means of an all-metal dissipating element through which water flows, all by **Federal Telecommunication Laboratories, Inc.,** 67 Broad St., New York 4, N. Y.

AN AMAZING IMPROVEMENT!

GLASER LECTRON ROSIN CORE SOLDER

Speeds soldering operations on the production line.

GLASER LECTRON ROSIN CORE SOLDER is superior to any other rosin core solder on the market. An outstanding achievement in the radio and electronic industries. Made with a specially "energized" rosin flux, an exclusive development of the Glaser Research Laboratories. More efficient and faster than ordinary rosin core solders. Speeds production and lowers your costs—so important in today's competitive market.

Glaser Lectron Rosin Core Solder bonds perfectly copper, brass, nickel, chrome and other metals—yet is non-corrosive and non-conductive.

Lower tin-content solder used with Glaser Lectron Rosin Flux does as good a job as higher tin solder with ordinary rosin flux. Requires minimum flux and gives you more solder for your money!

Available in any tin-lead composition and wire gauge.

For greater economy in all soldering operations use Glaser Lectron Rosin Core Solder

Our Engineering Department is at your service in solving any soldering problem, without obligation. Contact us promptly.

SEE US AT THE I.R.E. SHOW
Grand Central Palace, Booth No. 260

Glaser SOLDER PRODUCTS

The Quality Line

GLASER LEAD CO., INC.
21-31 Wyckoff Avenue, Brooklyn 27, N.Y.

Manufacturers of the famous Glaser Quality Line of Solders, Fluxes and Tinning Compounds.

OUR 27TH YEAR OF DEPENDABLE SERVICE TO AMERICAN INDUSTRIES

Is Your File of Standards Complete?

For your convenience a list of up to date IRE Standards and the ASA Standards sponsored by IRE is given below. The coupon at the bottom may be used for your convenience in ordering standards which you may not have. The standards are punched for 3 ring book and can be permanently filed conveniently.

Current IRE Standards

Price

1) Standards on Electroacoustics, 1938 Definitions of Terms, Letter and Graphical Symbols, Methods of Testing Loud Speakers.
(vi + 37 pages, 6 x 9 inches).... $0.50

2a) Standards on Electronics: Definitions of Terms, Symbols, 1938.
A Reprint (1943) of the like-named section of "Standards on Electronics, 1938." (viii + 8 pages, 8½ x 11 inches) $0.20

2b) Standards on Electronics: Methods of Testing Vacuum Tubes, 1938.
A Reprint (1943) of the like-named section of "Standards on Electrons, 1938." (viii + 8 pages, 8½ x 11 inches) $0.50

3a) Standards on Transmitters and Antennas: Definitions of Terms, 1938.
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3b) Standards on Transmitters and Antennas: Methods of Testing, 1938.
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5a) Standards on Radio Wave Propagation: Definitions of Terms, 1942.
(vi + 8 pages, 8½ x 11 inches) .. $0.20

5b) Standards on Radio Wave Propagation: Measuring Methods, 1942.
Methods of Measuring Radio Field Intensity, Methods of Measuring Power Radiated from an Antenna, Methods of Measuring Noise Field Intensity. (vi + 16 pages, 8½ x 11 inches) $0.50

5c) Standards on Radio Wave Propagation: Definiitons of Terms Relating to Guided Waves, 1945.
(iv + 4 pages, 8½ x 11 inches).. $0.20

6a) Standards on Facsimile: Definitions of Terms: 1942.
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7) Standards on Piezoelectric Crystals: Recommended Terminology, 1945.
(iv + 4 pages, 8½ x 11 inches) ... $0.20

8a) Standards on Television: Methods of Testing Television Transmitters, 1947.
(vi + 18 pages, 8½ x 11 inches) ... $0.75

8b) Standards on Television: Methods of Testing Television Receivers, 1948.
(vi + 32 pages, 8½ x 11 inches) .. $1.00

8c) Standards on Television: Definitions of Terms, 1948.
(iv + 4 pages, 8½ x 11 inches)... $0.50

9) Standards on Antennas, Modulation Systems, and Transmitters: Definitions of Terms, 1948.
(vi + 25 pages, 8½ x 11 inches) ... $0.75

10) Standards on Abbreviations, Graphical Symbols, Letter Symbols, and Mathematical Signs, 1948.
(vi + 21 pages, 8½ x 11 inches) .. $0.75

11) Standards on Antennas: Methods of Testing, 1948.
(vi + 18 pages, 8½ x 11 inches) .. $0.75

Normas Sobre Receptors de Radio, 1938.*
A Spanish-language translation of "Standards on Radio Receivers, 1938," by the Buenos Aires Section of The Institute of Radio Engineers. (vii + 64 pages, 6 x 9 inches) Two Argentine Pesos (Postpaid)

** Not carried in stock at IRE Headquarters in New York. Obtainable only from Señor Domingo Arbó, Editor of Revista Telegrafica, Peru, 165, Buenos Aires, Argentina.*

ASA STANDARDS

(Sponsored by the IRE)

ASA1) American Standard: Standard Vacuum-Tube Base and Socket Dimensions.
(ASA C16.2-1939.) (8 pages, 7¾ x 10⅝ inches) $0.20

ASA2) American Standard: Manufacturing Standards Applying to Broadcast Receivers.
(ASA C16.3-1939.) (16 pages, 7¾ x 10⅝ inches) $0.20

ASA3) American Standard: Loudspeaker Testing.
(ASA C16.4-1942.) (12 pages, 7¾ x 10⅝ inches) $0.25

ASA4) American Standard: Volume Measurements of Electrical Speech and Program Waves.
(ASA C16.5-1942.) (8 pages, 7¾ x 10⅝ inches) $0.20

THE INSTITUTE OF RADIO ENGINEERS, INC.
1 East 79th St., New York 21, N.Y.

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Section Meetings 36A
Student Branch Meetings 42A
Membership 48A
Positions Open 50A
Positions Wanted 56A
News—New Products 83A

DISPLAY ADVERTISERS

Aircraft Radio Corp. 40A
Alfax Paper & Eng. Co. 91A
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American Lava Corp. 17A
Amperite Co. 76A
Andrew Corp. 46A
Arnold Engineering Co. 4A
Astatic Corp. 36A
Audio Development Co. 48A

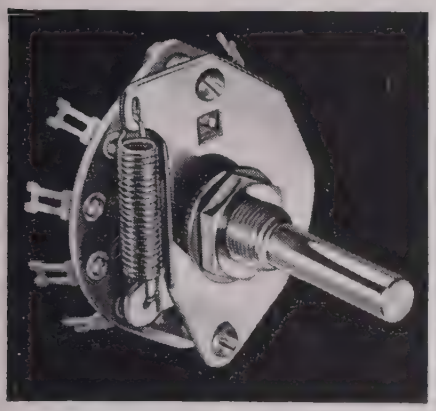
Bell Telephone Labs. 24A
Bendix Aviation Corp. (Radio Div.) 54A
Berkeley Scientific Co. 81A
Bliley Electric Co. 6A
Boonton Radio Corp. 67A
British Industries 41A
W. J. Brown 95A
Browning Laboratories 78A
Bud Radio, Inc. 64A
Burnell & Co. 45A

Cambridge Thermionic Corp. .. 22A
Cannon Electric Dev. Co. 80A
Capitol Radio Eng. Inst. 87A
Centralab ..... 12A, 34A, & 35A
C. P. Clare & Co. 55A
Cleveland Container Co. 27A
Sigmund Cohn Corp. 90A
Communications Equipment Co. 59A
E. J. Content 95A
Continental Carbon Inc. 86A
Cornell-Dubilier Electric Corp. ..... Cover III
Crosby Labs. 95A

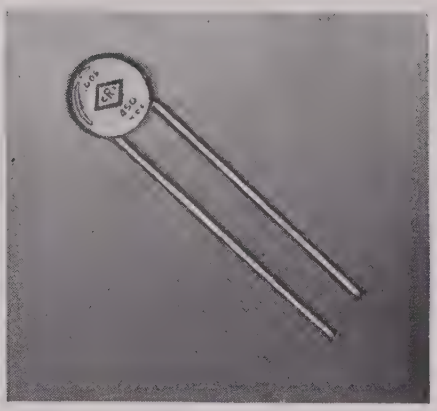
Daven Co. 56A
Distillation Products, Inc. 73A
Allen B. DuMont Laboratories 3A, 65A

Eitel-McCullough, Inc. 18A
Electrical Reactance Corp. 5A
Electro-Motive Mfg. Co., Inc. 21A
Electro Tech Equipment Co. ... 86A
Electro-Voice, Inc. 58A
Erie Resistor Corp. 13A

Electronic Industry

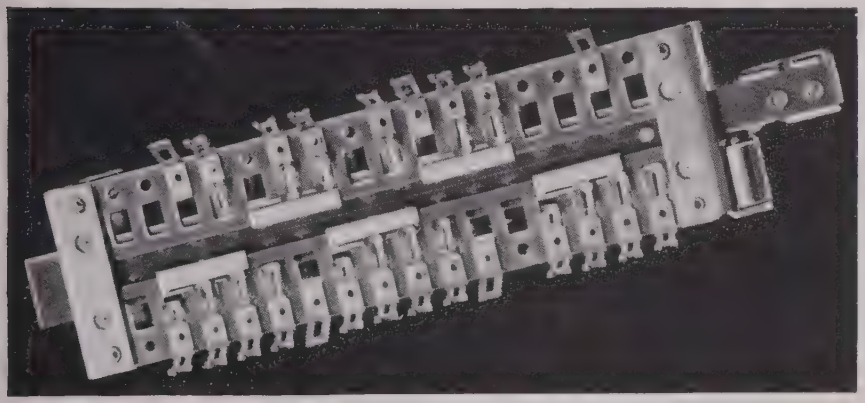


4 Great step forward in switching is CRL's New *Rotary Coil and Cam Index Switch.* Its coil spring gives you smoother action, positive indexing, longer life.

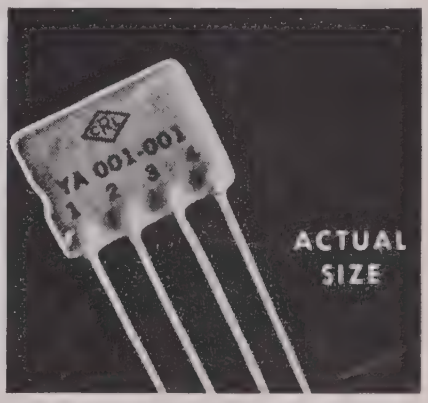


5 To CRL's line of high quality ceramic capacitors, these miniature disc *Hi-Kaps* have been added. Combine reliability, capacity. Order Bulletin 933.

6 Wide range of variations in CRL's Model "M" Radiohm simplifies production and inventory. Bulletin 697-A illustrates convenience, versatility!



7 Centralab's development of a revolutionary, new Slide Switch promises improved AM and FM performance! Flat, horizontal design saves valuable space, allows short leads, convenient location to coils, reduced lead inductances for increased efficiency in low and high frequencies. Rugged, efficient. Write for Bulletin 953.



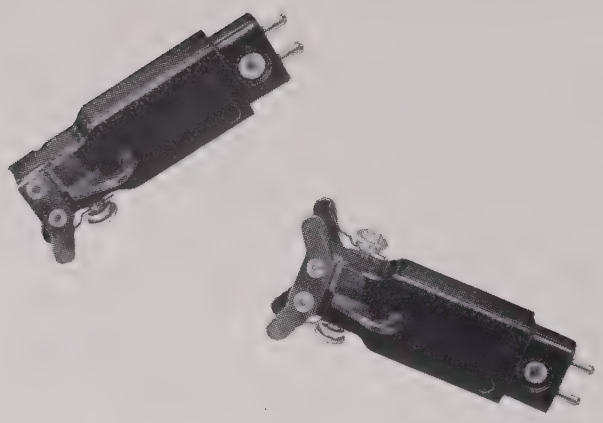
8 CRL's *Couplate* consists of a plate lead resistor, grid resistor, plate by pass capacitor and coupling capacitor. Write for Bulletin 943.

LOOK TO CENTRALAB IN 1949! ***First in component research that means lower costs for the electronic industry. If you're planning new equipment, let Centralab's sales and engineering service work with you. Get in touch with Centralab!***

Centralab

CRL

DIVISION OF GLOBE-UNION INC., MILWAUKEE, WIS.



Here are the superlative new Series of Shure "Vertical Drive" Crystal Cartridges. They reproduce *all* the recorded music on the *new* wide-range high-fidelity pressings. Unusually highly compliant, these "Vertical Drive" Cartridges will faithfully track standard records with a force of only 8 grams—micro-groove records with a force of only 5 grams (an added protection for treasured recordings). Will fit standard or special mountings. Have more than adequate output for the average audio stage. They are requisites for the critical listener . . . the lover of fine music. They are especially recommended for those applications where *true fidelity* is essential. Available in single needle and dual needle turnover models—as illustrated above.

For full details, write on company letterhead to Dept. "I."

Licensed under patents of Brush Development Company. Shure patents pending.

SHURE

SHURE BROTHERS, INC.

Microphones and Acoustic Devices

225 WEST HURON STREET, CHICAGO 10, Ill. • CABLE ADDRESS: SHUREMICRO

SECTION MEETINGS

BALTIMORE

"Systems Research in its Origin, Organization, and Aims," by F. Hamburger, Jr., The Johns Hopkins University; December 21, 1948.

"A Recording Photometer," by E. J. King, The Johns Hopkins University; December 21, 1948.

"An Audio Sweep Frequency Oscillator," by R. G. Roush, The Johns Hopkins University; December 21, 1948.

CEDAR RAPIDS

"Some Aspects of VHF Propagation," by D. E. Kerr, Massachusetts Institute of Technology; December 15, 1948.

CLEVELAND

"Physics of Music," by W. Mack, Radio Station WGAR; December 16, 1948.

DAYTON

"Electronic Generation of Musical Tones," by J. Jordan, Baldwin Piano Company; January 6, 1949.

DETROIT

"Ultra-High Frequency Antennas and Transmission Lines," by R. M. Krueger, American Phenolic Corporation; November 19, 1948.

"The Design and Application of Radio Communication Equipment for Railroads," by C. N. Kimball, Bendix Aviation Corporation; December 17, 1948.

Election of Officers; December 17, 1948.

HOUSTON

"Installation and Operating Problems of TV Station KLEE," by P. Huhndorff, Radio Station KLEE-TV; December 17, 1948.

LOUISVILLE

"Design and Manufacture of Home Television Receivers," by E. L. Clark, RCA-Victor Home Instrument; January 14, 1949.

PHILADELPHIA

"Development of a Large Metal Kinescope for Television," by H. P. Steier, RCA Victor Division; January 6, 1949.

PORTLAND

"Microwave Radio Application to Power Systems," by R. F. Stevens, Bonneville Power Administration; January 6, 1949.

PRINCETON

"The Teleran System of Air Navigation," by J. N. Marshall, RCA Victor Division; January 13, 1949.

SALT LAKE

"Microwave Amplification Using Traveling Waves and Electron Waves," by C. F. Quate, Stanford University; December 29, 1948.

SAN DIEGO

"Recent Developments in Sound Recording," by J. G. Frayne, Western Electric Company; December 7, 1948.

"Factors Which Contribute to Pleasantness in Listening," by J. P. Maxfield, United States Navy Electronics Laboratory; January 4, 1949.

Election of Officers; January 4, 1949.

(Continued on page 38A)

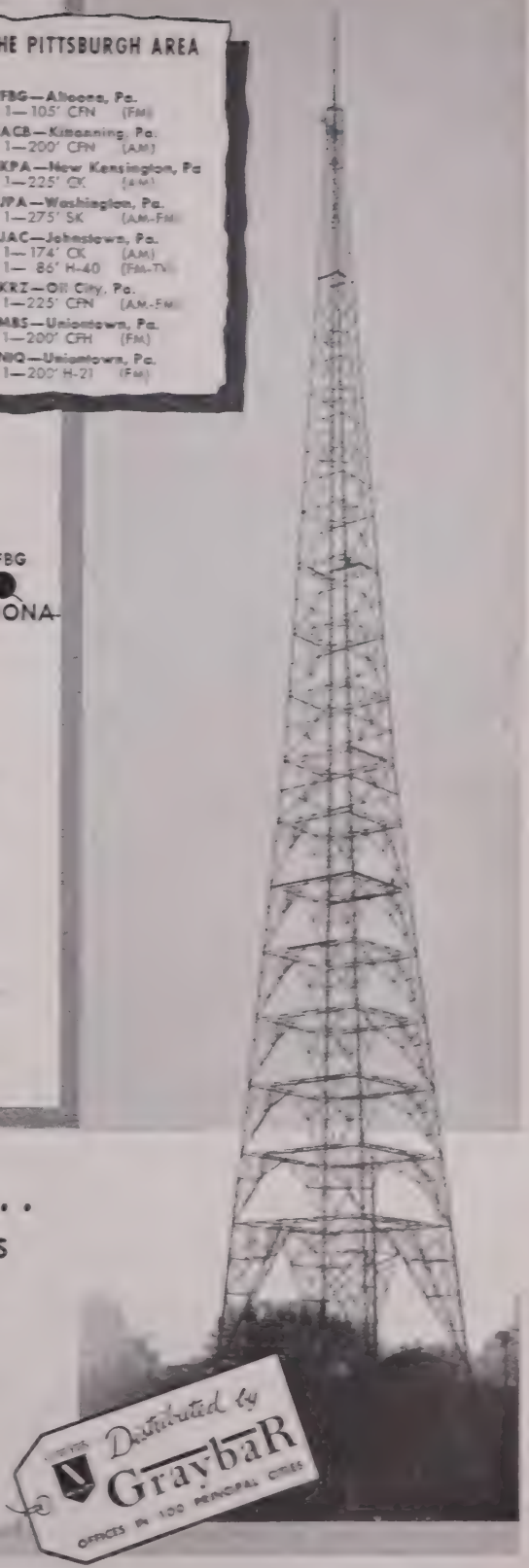
WHERE COMPETITION IS KEENEST...

BLAW-KNOX TOWERS DOMINATE THE AIRWAYS

That "still, small voice in the wilderness" hasn't a chance around Pittsburgh. To be heard above the electronic babble it must come out loud, strong and clear.

Receivers tuned to the stations shown here find clear, sharp signals broadcast via Blaw-Knox Antenna Towers . . . Radio engineers know you can "hear the difference."

BLAW-KNOX DIVISION OF BLAW-KNOX COMPANY
2037 Farmers Bank Bldg., Pittsburgh, Pa.



BLAW-KNOX ANTENNA TOWERS

Speaking of Percentages

THE

MYCALEX

CORPORATION OF AMERICA

sincerely believes that every user of insulation will be interested in the following progress report on Mycalex 410, molded—exclusive formulation of the Mycalex Corp. of America—for the four year period, 1945-1948:

- Average selling price of Mycalex 410 *reduced* by more than 50% over the past four year period.
- Raw material costs *increased* approximately 150%.
- Labor costs to make Mycalex 410 *increased* approximately 50%.
- Demand and production of Mycalex 410 *increased* approximately 500%.

The constantly increasing number of users of Mycalex 410 have benefited—with a better product—better service and deliveries—at a *lower cost.*

Research, plant expansion, improved engineering, additional new efficient manufacturing equipment—have permitted us to make available in increased quantities——Mycalex 410—molded—at prices comparable to other less efficient molded insulations.

MYCALEX 410 is now priced to meet rigid economy requirements

Send us your blue prints. We can handle the tough jobs as well as the less complicated ones. Any interest evidenced on your part in Mycalex products and services—will receive the prompt, courteous and intelligent attention of a competent Mycalex factory sales engineer. He will receive the fullest backing and cooperation from other factory executives—to serve you promptly—with a quality product and at an economical and fair price.

SINCE 1919 MYCALEX THE INSULATOR

SECTION MEETINGS

(Continued from page 36A)

SUBSECTIONS

MONMOUTH

"Recent Advances in the Theory of Communication," by C. E. Shannin, Bell Telephone Laboratories; January 19, 1949.

LANCASTER

"Modern Electronic Computers—Their Design and Application" by P. Crawford, Jr., Office of Naval Research; January 12, 1949.

WINNIPEG

"Frequency Allocations," by C. J. Acton, Department of Transportation, Ottawa; October 13, 1948.

STUDENT BRANCH MEETINGS

UNIVERSITY OF ALBERTA—IRE BRANCH

Westinghouse Films "Electronics at Work" and "Summer Storm"; January 11, 1949.

UNIVERSITY OF ARIZONA—IRE-AIEE BRANCH

"New Electrical Horizons," by W. C. Smith, General Electric Company; December 16, 1948.

CALIFORNIA STATE POLYTECHNIC COLLEGE—IRE BRANCH

"Job Hunting Through Letters," by J. P. Riebel, California State Polytechnic College; January 10, 1949.

UNIVERSITY OF CALIFORNIA—IRE-AIEE BRANCH

"Blowing Fuzes," by N. S. Beyer, Bussman Fuse Company; November 18, 1948.

"Magnetic Tape Recorders," by H. Lindsay, Ampex Tape Recording Company; December 15, 1948.

"New Horizons in Electrical Engineering," by W. C. Smith, AIEE Board Member; January 6, 1949.

CASE INSTITUTE OF TECHNOLOGY—IRE BRANCH

Election of Officers; January 4, 1949.

Forum, "Job Opportunities," J. W. Bird, RCA; F. H. Knapp, Bell Telephone; and T. Friedman, Radio Station WXEL; January 12, 1949.

"Application of Radar to Aircraft Operations," by G. Brodie, National Advisory Council on Aeronautics; January 18, 1949.

COLUMBIA UNIVERSITY—IRE-AIEE BRANCH

"Serendipity," by W. C. White, General Electric Company; December 11, 1948.

ILLINOIS INSTITUTE OF TECHNOLOGY—IRE BRANCH

"Aircraft Blind Landing Systems," by G. Doland, Student, Illinois Institute of Technology; January 6, 1949.

(Continued on page 40A)

MYCALEX 410 MAKES HISTORY

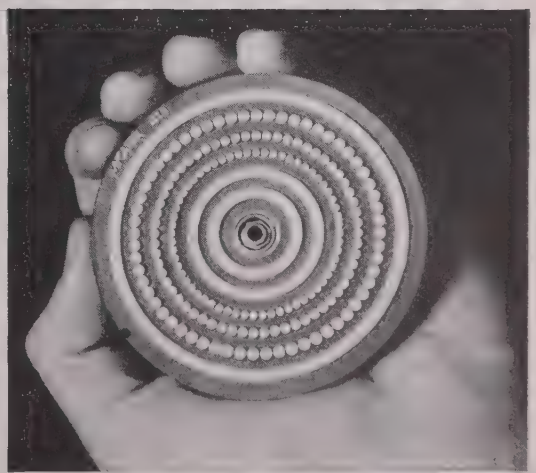
Sets astonishing high operational record for telemetering commutator used on aeronautical research projects . . . MYCALEX 410 only insulation to fill exacting requirements.

Illustrated are top and bottom views of the MYCALEX 410 molded insulation commutators manufactured to the specifications of Raymond Rosen Engineering Products, Inc., for Air Material Command and Navy telemetering projects. This commutator, with 180 contacts and 3 slip rings of coin silver, samples sixty channels of information such as air speed, altitude, angle-of-attack, temperature, pressure, voltage and other variables; and provides thirty synchronizing pulses.

To February 7, 1949, more than 200 hours of maintenance free, high speed, clean signal telemetering commutator performance has been logged on MYCALEX 410 Units. . . . Experience indicated four hours was optimistic . . . specifications hoped for ten hours . . . and the challenging problem was solved by MYCALEX 410 molded insulation.

SPECIFICATIONS TO BE MET IN PRODUCING MYCALEX 410 MOLDED INSULATION COMMUTATORS FOR TELEMETERING

O.D. 2.996" + .000 — .002 • Location of 3 slip rings and the 3 contact arrays from the center has a total tolerance of ± .001. • Contact spacing 6° apart ± 1 minute. • Parting line thicknesses on insulation body are + .002 —.000. • Concentricity between ball bearing bushing and O.D. .0015. • Assembly height from face of slip rings and contacts to Mycalex 410 has tolerance of + .002 —.000. • Every contact must be tested from its neighbor contact for infinity on a 500 volt megger meter • Plate ambient −20° C. to + 100° C. • Plate to operate at 95% humidity must not warp, crack, change in dielectric constant or resistivity • Contacts to resist high temperatures and must not loosen when repeatedly heated by soldering.



MYCALEX 410 molded insulation is designed to meet the most exacting requirements of all types of high frequency circuits. Difficult, involved and less complicated insulation problems are being solved by MYCALEX 410 molded insulation . . . the exclusive formulation of MYCALEX CORP. OF AMERICA . . . our engineering staff is at your service.

SPECIFY MYCALEX 410 for Low Dielectric loss. . . . High Dielectric strength. . . . High Arc Resistance. . . . Stability over wide Humidity and Temperature changes. . . . Resistance to High Temperatures. . . . Mechanical Precision. . . . Mechanical Strength. . . . Metal Inserts Molded in Place. . . . Minimum Service Expense. . . . Cooperation of MYCALEX Engineering Staff.

SINCE 1919 MYCALEX THE INSULATOR TRADE MARK REG. U.S. PAT. OFF.

MYCALEX CORP. OF AMERICA

"Owners of 'MYCALEX' Patents"

Plant and General Offices, CLIFTON, N. J. *Executive Offices, 30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.*

AIRCRAFT
RADIO
CORPORATION

Announces

THE TYPE H-12

SIGNAL GENERATOR

900-2100 Megacycles

. . . for research and for production testing

- 900-2100 megacycles, single band
- Continuous coverage with single-dial control directly calibrated
- Directly calibrated attenuator, 0 to -120 dbm
- CW or AM pulse modulation
- Extensive pulse circuitry

Write for details

Aircraft Radio Corporation
BOONTON, New Jersey

ARC

Dependable Electronic Equipment Since 1928

STUDENT BRANCH MEETINGS

(Continued from page 38A)

STATE UNIVERSITY OF IOWA—IRE BRANCH

"Photo-Flash," by R. Dahlin, Student, State University of Iowa; January 5, 1949.

"Types of Switches and Broadcast Switching," by J. A. Green, Collins Radio Company; January 12, 1949.

JOHN CARROLL UNIVERSITY—IRE BRANCH

"Electronics in the Field of Seismology," by E. F. Carome, Student, John Carroll University; November 27, 1948.

"Applications of Electronics in Physical Chemistry," by E. B. Thomas, John Carroll University; November 29, 1948.

"Basic Theory of Operation of Radar Systems," by T. J. Dugan, Student, John Carroll University; January 18, 1949.

LAFAYETTE COLLEGE—IRE-AIEE BRANCH

"The Oscilloscope," by J. Wilson, Student, Lafayette College; January 13, 1949.

"James Maxwell." by D. R. Albus, Student, Lafayette College; January 13, 1949.

"Summer Employment with Pennsylvania Power and Light," by W. Rohland, Student, Lafayette College; January 13, 1949.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY—IRE-AIEE BRANCH

Election of Officers; October 20, 1948.

Motion Pictures, "Crystal Clear and Coaxial," from the American Telegraph and Telephone Co.

"The Opportunities in Government Work in the Naval Ordnance Laboratory and the Bureau of Standards," by R. Weller, Naval Ordnance Laboratory, and J. Hilsenrath, Bureau of Standards; December 15, 1948.

"Construction and Installation of WBZ Television," by S. V. Statig, Radio Station WBZ-TV; November 3, 1948.

MICHIGAN STATE COLLEGE—IRE-AIEE BRANCH

"Favorite Misconceptions of Electrical Engineers," by W. Richter, Allis-Chalmers; January 19, 1949.

UNIVERSITY OF MICHIGAN—IRE-AIEE BRANCH

"Industrial Applications of Rototrol Regulators," by M. H. Fisher, Westinghouse Electric Corporation; January 12, 1949.

MISSOURI SCHOOL OF MINES—IRE-AIEE BRANCH

"Prospects of Television and the IRE," by T. A. Hunter, Hunter Manufacturing Company; January 6, 1949.

Election of Officers; January 6, 1949.

COLLEGE OF THE CITY OF NEW YORK—IRE BRANCH

"FM Tuners," by C. L. Fruchter, Student, College of the City of New York; December 14, 1948.

"Television Design and Production Techniques," by S. Napolin, Pilot Radio Corporation; December 21, 1948.

Election of Officers; January 4, 1949.

Report on Field Trip to radiostation WABD.

NEW YORK UNIVERSITY—IRE BRANCH

"Stamped Wiring," by M. Ackerman, Franklin Airloop Corporation; December 18, 1948.

"Sunspots and Their Effect on Radio Reception and Transmission," by J. H. Nelson; RCA Communications; December 18, 1948.

"Watch Tick Analyzer," by G. Stewart, American Time Company; December 18, 1948.

(Continued on page 42A)

When it's

HEAT

you have to beat

Specify

"NOFLAME-COR"

the TELEVISION hookup wire

by CORNISH

- ✓ Flame Resistant
- ✓ Heat Resistant
- ✓ High Dielectric
- ✓ High Insulation Resistance
- Easy Stripping
- ✓ Facilitates Positive Soldering
- ✓ Also unaffected by the heat of impregnation—therefore, ideal for coil and transformer leads

RUBBER	75°
PLASTIC	80°
"NOFLAME-COR"	90°

COMPLETE ENGINEERING DATA AND SAMPLES ON REQUEST

approved by Underwriters Laboratories at

90° CENTIGRADE — **600** VOLTS

Proven BEST by exhaustive tests! Leading producers of television, F-M, quality radio and all exacting electronic applications specify our Underwriter Approved "NOFLAME-COR" as a MUST. Immediate delivery. All sizes, solid and stranded. Over 200 color combinations.

"made by engineers for engineers"

CORNISH WIRE COMPANY, Inc.

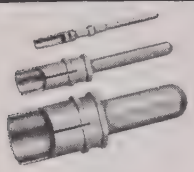
605 North Michigan Avenue, Chicago 11 — 15 Park Row, New York 7, N. Y. — 1237 Public Ledger Bldg., Philadelphia 6

MANUFACTURERS OF QUALITY WIRES AND CABLES FOR THE ELECTRICAL AND ELECTRONIC INDUSTRIES

AMPHENOL

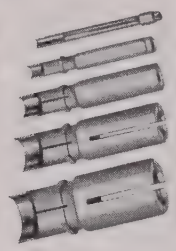
"AN" Type CONNECTOR Features

CONTACTS



Pin Contacts

Carefully tested high conductivity alloys are used in the manufacturing of contacts in Amphenol "AN" connectors. An unusually compact unit with high current carrying capacity and low voltage drop is provided by Amphenol-engineered design. Pin elements available in pressurized and explosion-proof construction.

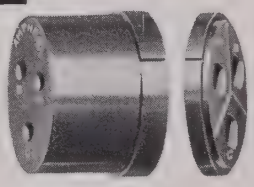


Socket Contacts

DIELECTRIC ELEMENTS

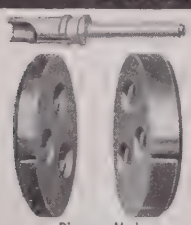
Pin Rear Insulator Pin Front Insulator

The dielectric material in Amphenol "AN" connectors is highest-grade thermosetting plastic, selected to provide high arc resistance, high impact strength, and negligible moisture absorption. Inserts and backing discs are the heaviest to be found in the AN connector field . . . made to withstand roughest handling and operating conditions.



Socket Front Insulator Socket Rear Insulator

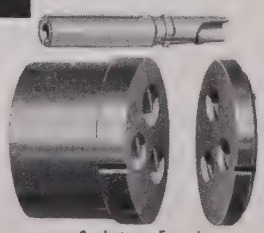
ASSEMBLY FEATURES



Pin or Male Insert Elements

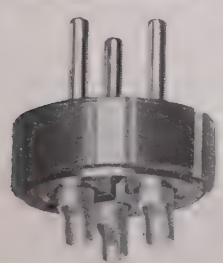
No auxiliary parts necessary to hold contacts in place . . . dielectric elements and contacts are especially designed for easy assembly.

Contact solder pockets in Amphenol connectors are always uniformly aligned and cannot turn. This feature saves as much as 40% in assembling time, making these connectors lowest in cost.



Socket or Female Insert Elements

INSERTS

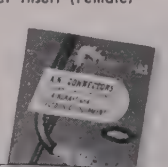


Pin Insert (Male)

"AN" connectors are available in five major shell designs, each accommodating over 200 styles of contact inserts. Interchangeable within the connector shells, either plug or receptacle can be supplied for the live side of the line. No auxiliary parts or tools are required to assemble the elements which are held securely in the connector shell by means of a phosphor bronze retainer ring.

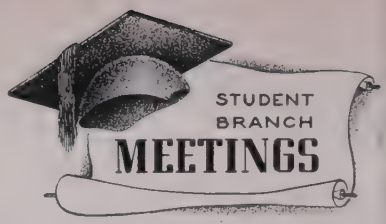
Socket Insert (Female)

Write for your copy of Amphenol's comprehensive and illustrated catalog on "AN" and "97" Connectors. Please send request on company letterhead to Dept. H.



AMERICAN PHENOLIC CORPORATION
1830 SO. 54TH AVENUE
CHICAGO 50, ILLINOIS

AMPHENOL



(Continued from page 40A)

UNIVERSITY OF NORTH DAKOTA—IRE-AIEE BRANCH

"The Field of Utility," by R. A. Billingsly, Northern States Power; January 12, 1949.

POLYTECHNIC INSTITUTE OF BROOKLYN—IRE BRANCH

"Selenium Rectifiers," by E. Steiker, Federal Telephone and Radio Corporation; November 18, 1948.

PRINCETON UNIVERSITY—IRE-AIEE BRANCH

"The Present Status of Television," by R. D. Kell, Radio Corporation of America; October 13, 1948.

"The Applications of Servo-Mechanisms in Industry," by M. A. Edwards, General Electric Company; December 15, 1948.

ST. LOUIS UNIVERSITY—IRE BRANCH

"Opportunities in the Public Utilities Field," by M. E. Skinner, Union Electric Company of Missouri; December 9, 1948.

SYRACUSE UNIVERSITY—IRE BRANCH

"Commercial Television Equipment," by D. W. Pugsley, General Electric Company; January 12, 1949.

UNIVERSITY OF WISCONSIN—IRE BRANCH

"Electronics in Medicine (Electroencephalography," by W. Gilson, University of Wisconsin; December 14, 1948.

The following transfers and admissions were approved and will be effective as of March 1, 1949:

Transfer to Senior Member

Babits, V. A., 180 Eighth, Troy, N. Y.
Bassett, D. M., 520 Corona Ave., Dayton 9, Ohio
Beckwith, J. R., Serapio Rendon #39, Mexico D. F., Mexico
Brown, H. A., 8 Fieldcourt, Bronxville, N. Y.
Frommer, J. C., 1525 Teakwood Ave., Cincinnati 24, Ohio
Gorham, J. E., 1312 Fourth Ave., Asbury Park N. J.
Houston, G. P., 3000 Manhattan Ave., Baltimore 15, Md.
Jacob, F. N., 5843 N. Rockwell St., Chicago 45, Ill.
Jarrett, M. G., 416 Seventh Ave., Pittsburgh 19, Pa.
Kurshan, J., RCA Laboratories, Princeton, N. J.
Maiden, R. M., 126 Danbury St., S.W., Washington 20, D. C.
McDowell, R. B., 2415 W. Cameron Rd., Falls Church, Va.
McGee, W. F., c/o Aeronautical Radio de Mexico S. A., Morelos 37, Mexico, D. F., Mexico
Moffat, W. H., 49 Clove Rd., New Rochelle, N. Y.
Muntz, W. E., 176 Forest Hill Dr., Syracuse, N. Y.
Pierce, F. W., 2415—19 Ave., Rock Island, Ill.
Robinson, R. O., Jr., 8912 First Ave., Silver Spring Md.
Shannon, C. E., Bell Telephone Laboratories, Murray Hill, N. J.

(Continued on page 44A)

For new simplicity, wide range, and high accuracy in the control of modern electronic circuits...

Cutaway view of the HELIPOT (Model A–10 Turn–1¾" Diameter

THE BECKMAN Helipot

(Trademark of the HELical POTentiometer)

Provides *many times* greater resistance control in *same* panel space as conventional potentiometers!

IF YOU are designing or manufacturing *any type* of precision electronic equipment be sure to investigate the greater convenience, utility, range and compactness that can be incorporated into your equipment by using the revolutionary HELIPOT for rheostat-potentiometer control applications...and by using the new DUODIAL turns-indicating knob described at right.

Briefly, here is the HELIPOT principle...whereas a conventional potentiometer consists of a *single* coil of resistance winding, the HELIPOT has a resistance element *many times* longer coiled *helically* into a case which requires no more panel space than the conventional unit. A simple, foolproof guide controls the slider contact so that it follows the helical path of the resistance winding from end to end as a single knob is rotated. Result ...*with no increase in panel space requirements*, the HELIPOT gives you as much as 12 times* the control surface. You get far greater accuracy, finer settings, increased range—with maximum compactness and operating simplicity!

COMPLETE RANGE OF TYPES AND SIZES

The HELIPOT is available in a complete range of types and sizes to meet a wide variety of control applications . . .

MODEL A: *5 watts, 10 turns, 46" slide wire length, 1¾" case dia., resistances 10 to 50,000 ohms, 3600° rotation.*

MODEL B: *10 watts, 15 turns, 140" slide wire length, 3¼" case dia., resistances 50 to 200,000 ohms, 5400° rotation.*

MODEL C: *3 watts, 3 turns, 13½" slide wire length, 1¾" case dia., resistances 5 to 15,000 ohms, 1080° rotation.*

MODEL D: *15 watts, 25 turns, 234" slide wire length, 3¼" case dia., resistances 100 to 300,000 ohms, 9000° rotation.*

MODEL E: *20 watts, 40 turns, 373" slide wire length, 3¼" case dia., resistances 150 to 500,000 ohms, 14,400° rotation.*

Also, the HELIPOT is available in various special designs . . . with double shaft extensions, in multiple assemblies, integral dual units, etc.

Let us study *your* potentiometer problems and suggest how the HELIPOT can be used—possibly is already being used by others in your industry—to increase the accuracy, convenience and simplicity of modern electronic equipment. No obligation, of course. Write today outlining your problem.

**Data for Model A, 1¾" dia. Helipot. Other models give even greater control range in 3" case diameters.*

THE BECKMAN Duodial

The inner, or Primary dial of the DUODIAL *shows exact angular position of shaft during each revolution. The outer, or Secondary dial shows number of complete revolutions made by the Primary dial.*

A multi-turn rotational-indicating knob dial for use with the HELIPOT and other multiple turn devices.

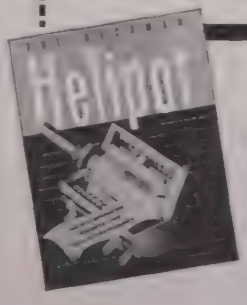
THE DUODIAL is a unique advancement in knob dial design. It consists essentially of a primary knob dial geared to a concentric turns-indicating secondary dial—and the entire unit is so compact it requires only a 2" diameter panel space!

The DUODIAL is so designed that—as the primary dial rotates through each complete revolution—the secondary dial moves one division on its scale. Thus, the secondary dial counts the number of complete revolutions made by the primary dial. When used with the HELIPOT, the DUODIAL registers *both* the angular position of the slider contact on any given helix as well as the particular helix on which the slider is positioned.

Besides its use on the HELIPOT, the DUODIAL is readily adaptable to other helically wound devices as well as to many conventional gear-driven controls where extra dial length is desired without wasting panel space. It is compact, simple and rugged. It contains only two moving parts, both made entirely of metal. It cannot be damaged through jamming of the driven unit, or by forcing beyond any mechanical stop. It is not subject to error from backlash of internal gears.

TWO SIZES—MANY RATIOS

The DUODIAL is now available in a 2" diameter model and soon will also be available in a new 4¾" diameter model for main control applications. Standard turns-ratios include 10:1, 15:1, 25:1 and 40:1 (ratio between primary and secondary dials). Other ratios can be provided on special order. The 10:1 ratio DUODIAL can be readily employed with devices operating *fewer* than 10 revolutions and is recommended for the 3-turn HELIPOT. In all types the primary dial and shaft operate with a 1:1 ratio, and all types mount directly on a ¼" round shaft.



Send for this
HELIPOT AND DUODIAL CATALOG!

Contains complete data, construction details, etc., on the many sizes and types of HELIPOTS...and on the many unique features of the DUODIAL. Send for your free copy today!

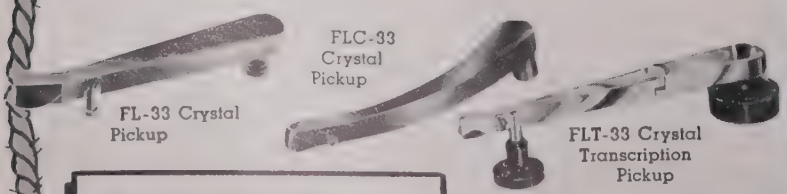
THE **Helipot** CORPORATION, SOUTH PASADENA 6, CALIFORNIA

New Astatic LONG-PLAYING PICKUPS are your...

...Neatest Answer TO A KNOTTY PROBLEM

THE FUTURE of long-playing records and the equipment to play them depends upon public **satisfaction** and **convenience.** For the present, to give both to the public requires a means of playing any type of record on one phonograph. That single unit must have an absolute minimum of extra trappings, and must operate with complete ease and simplicity.

Phonograph owners whose sets operate with an Astatic FL Series Pickup are enthusiastically satisfied, encounter no inconvenience. Their set includes only one pickup. They have no limitations on the type of record they can buy. For, Astatic FL Pickups play all three types of records—33-1/3, 45 and 78 RPM. They switch from one to the other WITHOUT CHANGING NEEDLE PRESSURE or making similar adjustments. All that need be done is to insert one tiny slip-in cartridge for any long-playing records, slip it out and insert another for 78 RPM recordings. It's so easy a child can make the change in seconds, for these specially designed cartridges seat themselves into playing position on the same slip-in principle which joins cap and barrel of many modern fountain pens. Entirely new pickup engineering provides the ultimate in clarity and depth of tone, absence of surface noise . . . assures perfect tracking at only five grams needle pressure.



Write for illustrated literature, complete details.

Astatic Crystal Devices manufactured under Brush Development Co. patents

THE Astatic CORPORATION
ASTATIC CONNEAUT, OHIO. CANADA: ONTARIO

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(Continued from page 42A)

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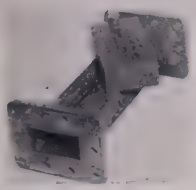
(Continued on page 46A)

MICROWAVE PLUMBING

10 CENTIMETER



WAVEGUIDE DIRECTIONAL COUPLER, 27 db. Navy type CABV1-47AAN, with 4 in. slotted section ..$42.50

Sq. Flange to rd choke adapter, 18 in. long OA 1½ in. x 3 in. guide, type "N" output and sampling probe ..$32.00

"S" BAND CRYSTAL MOUNT, gold plated, with 2 type "N" connectors $12.50

MAGNETRON TO WAVEGUIDE coupler with 721-A duplexer cavity, gold plated $45.00

10 CM WAVEGUIDE SWITCHING UNIT, switches 1 input to any of 3 outputs. Standard 1½" x 3" guide with square flanges. Complete with 115 vac or dc arranged switching motor. Mfg. Raytheon. New and complete $150.00

721-A TR CAVITY WITH TUBE. Complete with tuning plungers $12.50

POWER SPLITTER: 726 Klystron input, dual "N" output $5.00

10 CM. McNALLY CAVITY Type SG $3.50

WAVEGUIDE SECTION, MC 445A, rt. angle bend, 5½" ft. OA. 8" slotted section $21.00

10 CM OSC. PICKUP LOOP, with male Homedell output $2.00

TS115/APS-2F 10 CM ANTENNA in lucite ball, with type "N" fitting $4.50

OAJ NAVY TYPE CYT66ADL, ANTENNA, in lucite ball, with Sperry fitting $4.50

10 CM FEEDBACK DIPOLE ANTENNA, in lucite ball, for use with parabola $8.00

10 CM END FIRE POLYRODS .....$1.75 ea.

"S" BAND Mixer Assembly, with crystal mount, pick-up loop, tunable output $3.00

⅞" RIGID COAX—⅜" I.C.

SLOTTED SECTION, 10 ft. L, 4" Slot $8.50

RIGHT ANGLE BEND, with flexible coax output pick-up loop $8.00

SHORT RIGHT ANGLE bend, with pressurizing nipple $4.00

RIGID COAX to flex coax connector $3.50

STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $7.00

RT. ANGLES for above $3.75

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MISCELLANEOUS

DEHYDRATING UNIT, 60 LB. CAP., 115 v, 60 cy oper. 24" x 22" x 15", New and Complete ..$425.00

F 129 SPR-2 Coax Wavetraps $12.50

3 CM. PLUMBING

(STD. 1" x ½" GUIDE UNLESS OTHERWISE SPECIFIED)

"X" BAND PREAMPLIFIER, consisting of 2-723A/B local oscillator-beacon feeding waveguide and TR/ATR Duplexer section, including 60 mc. IF amp. $47.50

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WAVEGUIDE SECTION, 1⅛" x ½" choke to choke, 4 ft. long $6.75

"X" BAND calibrated attenuator $85.00

SHIELDED KLYSTRON tube mounts with rough attenuator outputs $90.00

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APS-10TR/ATR duplexer section with additional iris flange $10.00

Flexible waveguide .....**$4.00 per ft.**

THERMISTOR: D-164699—for mtg. in "X" Band Guide $2.50

45 DEG. TWIST, 6" Long $8.50

12" SECTION, 45 deg. twist, 90 deg. bend $6.00

11" STRAIGHT WAVEGUIDE section choke to cover. Special heavy construction, silver plated $4.50

15 DEG. BEND, 10" choke to cover $4.50

5 FT. SECTIONS, choke to cover, silver plated $14.50

18" FLEXIBLE SECTION $17.50

"E" or "H" PLANE BEND $12.50

BULKHEAD FEED THRU $15.00

WAVEGUIDE SECTION, CG 251/APS-15A, 26" long choke to cover, with 180 deg. bend of 2½" rad. at one end $6.00

ROTARY JOINT with slotted section and type "N" output pickup $17.50

WAVEGUIDE SECTION, 12" long choke to cover, 45 deg. twist & 2½" radius, 90 deg. bend $5.00

SLUG, TUNER/ATTENUATOR, W.E. guide, gold plated $6.50

TR/ATR DUPLEXER section with iris flange ..$8.00

TWIST, 5" 90 deg. choke to cover $5.00

WAVEGUIDE SECTIONS 2½ ft. long, silver plated, with choke flange $5.75

WAVEGUIDE, 90 deg. bend E plane, 13" long..$5.00

ROTARY JOINT, choke to choke $17.50

ROTARY JOINT, choke to choke, with deck mounting $17.50

S-CURVE WAVEGUIDE, 8" long cover to choke..$3.50

3" **FLEX SECTION.** Sq. flange to circ. flange adapter $7.50

"X" BAND WAVEGUIDE, 1¼" x ⅝" OD, 1/16" wall aluminum .....per ft. $ .75

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724-A TR tube (41-TR-1) $2.50

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TUBE	FREQ. RANGE	PK. PWR. OUT.	PRICE
2J31	2820-2860 mc.	265 KW.	$25.00
2J21-A	9345-9405 mc.	50 KW.	$25.00
2J22	3267-3333 mc.	265 KW.	$25.00
2J26	2992-3019 mc.	275 KW.	$25.00
2J27	2965-2992 mc.	275 KW.	$25.00
2J32	2780-2820 mc.	285 KW.	$25.00
2J38 Pkg.	3249-3263 mc.	5 KW.	$35.00
2J39 Pkg.	3267-3333 mc.	87 KW.	$35.00
2J40	9305-9325 mc.	10 KW.	$65.00
2J49	9000-9160 mc.	58 KW.	$85.00
2J55 Pkg.	9345-9405 mc.	50 KW.	$35.00
2J61	3000-3100 mc.	35 KW.	$65.00
2J62	2914-3010 mc.	35 KW.	$65.00
3J31	24,000 mc.	50 KW.	$55.00
5J30			$39.50
714AY			$25.00
718DY			$25.00
720BY	2800 mc.	1000 KW.	$50.00
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730-A	9345-9405 mc.	50 KW.	$25.00

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417A $25.00 2K41 $65.00

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4850	¾ in.	⅝ in.	$12.50
1500	1⅝ in.	1½ in.	$12.50
D161392*	1⅝ in.	1 5/16 in.	$12.50

* Mfr's Number.

TUNABLE PKGD. "CW" MAGNETRONS

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MIT. MOD. 3 HARD TUBE PULSER: Output Pulse Power: 144 KW (12 KV at 12 amp). Duty Ratio: .001 max. Pulse duration: 5, 1.0, 2.0 microsec. Input voltage: 115 v, 400 to 2400 cps. Uses 1-715-B, 1-829-B, 3-72's, 1-73. New $110.00

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G.E. #K2731 Repetition Rate: 635 PPS. Pri. Imp: 50 Ohms. Sec. Imp: 450 Ohms. Pulse Width: 1 Microsec Pri. Input: 9.5 KV PK, Sec. Output: 28 KV PK Peak Output: 800 KW. Biflar 2.75 Amp. $64.50

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G.E. K2450A Will receive 13KV, 4 micro-second pulse on pri., secondary delivers 14KV. Peak power out 100KW GE $45.00

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KS 8767: Fil. Xfmr. Pri: 115 v. 60 cy, Sec: 2 wdgs 5v. at 5 amp each. 15,000 v. ins. $15.00

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.25 MFD., 20,000 vdc $17.50

10 MFD., 1000 vdc $1.79

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.1 MFD., 6000 vdc, 25F509G2 .....$6.50

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PE 218-E: Input: 25-28 vdc. 92 amp. Output: 115 v. 350-500 cy. 1500 volt-amps. Dim: 17" x 6¼" x 10". New, export packed $49.95

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PE 206: Input: 28 vdc. 38 amps. Output: 80 v 800 cy, 500 volt-amps. Dim: 13" x 5⅝" x 10¼". New $12.50

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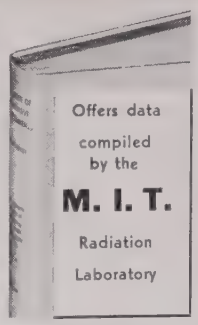

Just Out

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(Continued on page 47A)

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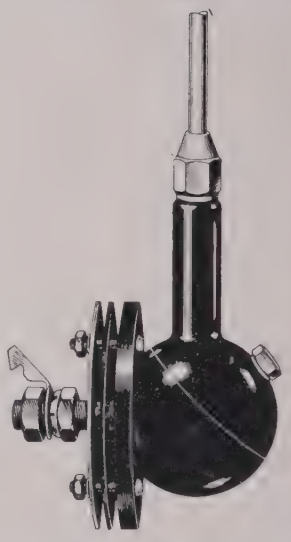

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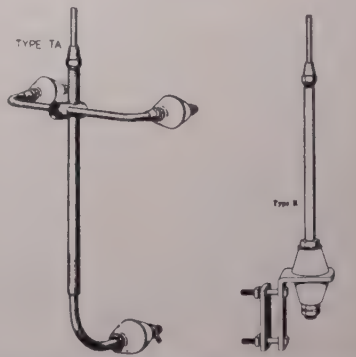

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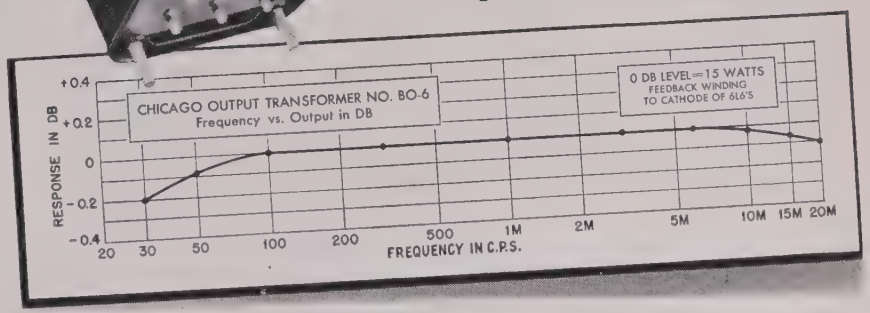

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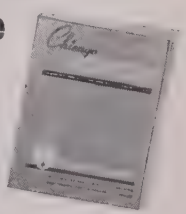

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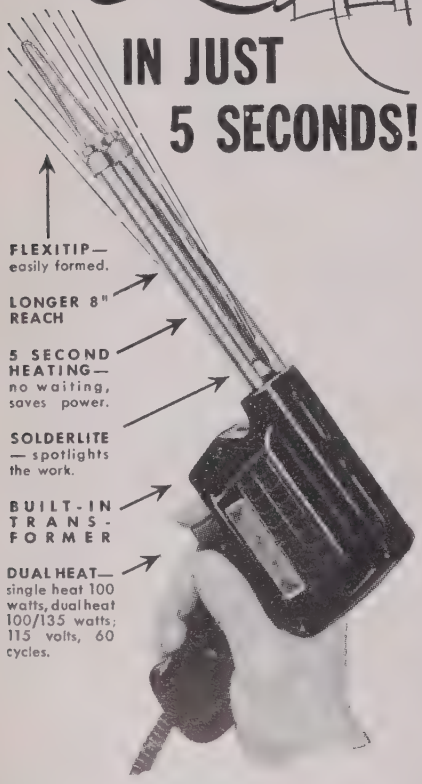
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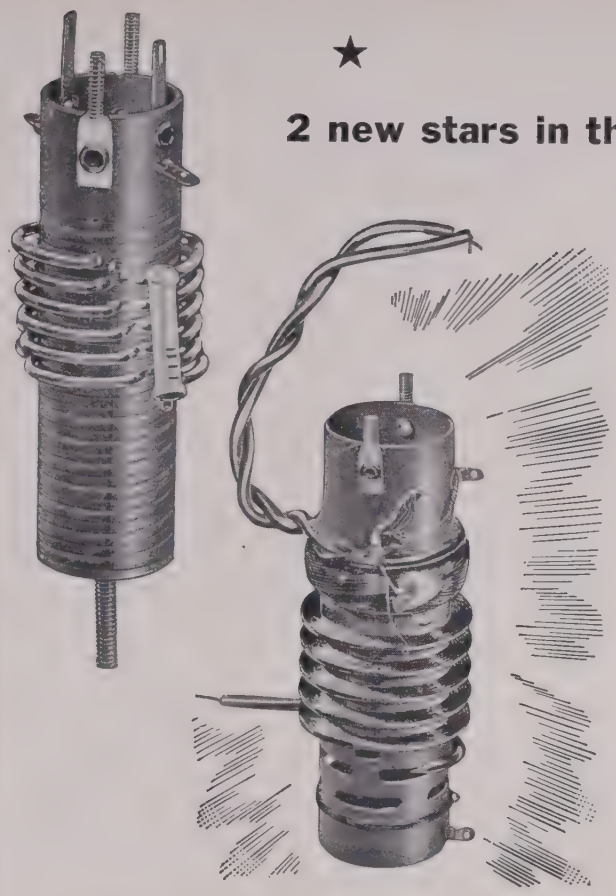

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career men in electronics

". . . so wide is the scope of radio science today, and so great its possibilities for the future, that it is beyond human power to foresee all the new advances that will appear; it is safe to prophesy that some developments will overshadow in significance many of the achievements of the past. This much is certain: our scientists and engineers will continue to devote their energies and skill toward extending the usefulness of the electronic and communication arts so that the Radio Corporation of America will remain World Leader in Radio—First in Television."

If You Are an Engineer or Physicist whose closest interests are wrapped up in the electronics of *tomorrow*, the above quotation from David Sarnoff's report on RCA operations during 1948 will be of special interest to you, for this quotation embodies in a few words the spirit which has always travelled in advance of RCA progress and achievement.

Today, as Never Before, RCA Victor Division of the Radio Corporation of America is engaged in far-reaching electronic developments whose horizons in the fields of radiation and sound extend four to five years, or more, into the future. These expanding horizons have created a large need for career men of talent —graduate electrical and mechanical engineers, physicists, with a thorough background in electronics and development-design experience in high-frequency and micro-wave techniques.

Working in Close Collaboration with distinguished scientists of RCA Laboratories, these men will work for RCA Victor in carrying basic research discoveries through the stages of advanced design and development. Unlimited laboratory resources and facilities are waiting for top-flight men ready to assume responsibilities in handling and administering advanced projects in virtually every phase of electronics—infrared, ultrasonic, audio and acoustic equipment; television receivers, antennas, transmitters, field and studio equipment; radar; mobile communications; aviation communications and navigational aids; coils, transformers and components.

These Openings Represent a permanent expansion in RCA Victor design and development activities, providing careers for men of high calibre with appropriate training and experience.

If You Meet These Specifications, and if you are looking for a career which will open wide the door to the complete expression of your talents in the fields of electronics, write, giving full details, to:

Arnold K. Weber, Personnel Manager
Box 122, RCA Victor Division
Radio Corporation of America
Camden, New Jersey

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

ELECTRONIC ENGINEERS—PHYSICISTS

A leading electronics company in Los Angeles, California offers permanent employment to persons experienced in advanced research and development. State qualifications fully. Box 545.

ENGINEERS—PHYSICISTS

Southwestern state college engaged in research, development and operation in guided missile field has openings for graduate electrical engineers or physicists with experience in electro-mechanical devices, telemetering, audio, RF, VHF and antenna design. Salary depends on education and experience which should be fully described in first letter. Box 554.

COMMUNICATIONS—ELECTRONICS ENGINEER

Work will involve aeronautical communications and aircraft electronic projects. Some development work but primarily application engineering. Box 555.

ENGINEERS AND PHYSICISTS

An expanded program of research has created opportunities in the fields of acoustics, hydrodynamics, electronics, mechanics and mathematics. Positions flexible enough to permit part-time college teaching if desired. Opportunity for graduate study. Salary commensurate with experience. Appointments carry academic rank ranging from Research Assistant to Professor. Inquiry invited. P.O. Box 30, State College, Pa.

ELECTRICAL AND ELECTRONICS ENGINEERS

The Engineer Research and Development Laboratories of the Corps of Engineers, located at Fort Belvoir, Virginia, has a continuing need for electrical and electronics engineers to fill positions involving design and development and paying entrance salaries, depending on grade, of from $3727.20 to $6235.00 per annum. Applications should be mailed to the Civilian Personnel Office, Bldg. 211, Fort Belvoir, Virginia.

ELECTRICAL ENGINEERS

1 experienced engineer wanted for each of the following: radar pulse circuit; circuit development; radar modulators; radar devices; radar receivers; radar indicator circuit design and development. Send resume in confidence to Box 556.

ELECTRONICS ENGINEER MANAGER

Openings in equipment Development Department of Electronics Division, Boston, Mass. for graduate engineer with ability to administer and direct an engineering activity. An electrical engineer

(Cotinued on page 51A)

Positions Wanted

(Continued from page 54A)

JUNIOR ENGINEER

B.S. radio and television engineering. American Television Institute of Technology, January 1949. Age 23. Married, no children. Desires position in research or design. Anywhere in U.S. Box 233 W.

TEACHING—PHYSICIST

Harvard Ph.D. expected June 1949 or a little later in theoretical physics. Some electronics background. Desires academic position with research possibilities. Box 234 W.

TELEVISION ENGINEER

Graduated American Television Institute of Technology October 1948 with B.S.T.E. Age 31. Married. 1st class F.C.C. license. 4 years maintenance Army radar equipment. Have been teaching advanced television for 15 months. Desires position as development or T.V. station engineer. Have a thorough understanding of R.C.A. and DuMont television equipment. Box 235 W.

INDUSTRIAL ELECTRONICS

B.S., B.E., M.E. June 1949, Yale. Age 24. Married. Desires job in industrial electronics. 2 years industrial engineering experience. Box 236 W.

COMMUNICATIONS ADMINISTRATOR

Communications and radio officer with experience in large size ships of the Fleet available in southwestern United States. 8 years experience Naval Communications Service, 12 years utility company, thoroughly conversant with communication problems. Age 43. Married. Own home. College training. Hold FCC license. Would consider airline, railway, transportation and oil companies, also sales with established company. Brochure available upon request. Box 237 W.

ELECTRONIC ENGINEER

B.E.E. Age 35. 2 years project engineering. Army, Navy project experience, 2 years Navy electronics, 3 years general engineering experience. Box 238 W.

ELECTRICAL ENGINEER

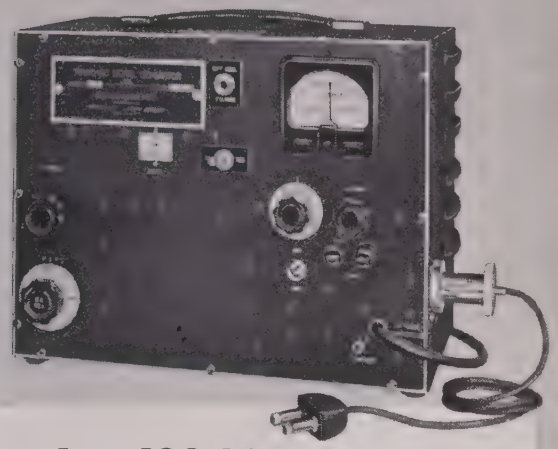
Graduate electrical engineer. Industrial experience with magnetic and electronic control. Army experience, radar repair and maintenance. Desires servomechanism research and design work. Member of Tau Beta Pi, Eta Kappa Nu. Box 239 W.

ASSISTANT PROFESSOR OR RESEARCH ENGINEER

E.E. degree. Lt. USNR, graduate work at Naval Academy. P. G. School Electronics Engineering. 2 years E.E. teaching all subjects. Desires position as assistant professor or research engineering. Middle west or south area. All offers carefully considered. Box 240 W.

(Continued on page 56A)

FREQUENCY MODULATED SIGNAL GENERATOR



MODEL 78FM

86-108 MC

Also Available For Other Frequency Ranges

1 to 100,000 MICROVOLTS

Variable Output

With Negligible Carrier Leakage

MODULATION: 400 cycle internal audio oscillator. Deviation directly calibrated: 0 to 30 kc. and 0 to 300 kc. Can be modulated from external audio source.

Audio fidelity is flat within 2 db from dc to 15,000 cycles. Distortion less than 1% at 75 kc. deviation.

The Model 78FM when used with Measurements Model M-275 Converter provides output in the IF ranges of 4.5, 10.7 and 21.7 mc.

Circular on Request

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
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¼ WATT—25¢

6.68Ω	12.32Ω	16.37Ω	123.8Ω	414.3Ω
10.48	13.02	20.	147.5	705
10.84	13.52	62.54	220.4	2193
11.25	13.89	79.81	301.8	10,000
11.74	14.98	105.8	366.6	59,148
				100,000

½ WATT—25¢

.250Ω	11.1Ω	235Ω	4,451Ω	15,000Ω
.334	13.15	260	5,000	15,750
.502	46	270	5,900	17,000
.557	52	298.3	6,500	20,000
.627	55.1	400	7,000	25,000
.76	75	723.1	7,500	30,000
1.01	97.8	2,500	8,000	37,000
1.53	125	2,850	8,500	100,000
2.04	180	3,427	10,000	150,000
2.25	210	4,000	14,825	

1 WATT—30¢

1.01Ω	5.21Ω	1,250Ω	18,000Ω	70,000Ω
2.58	10.1	3,300	50,000	75,000
3.39	10.9	7,000	55,000	
5.05	270	9,000	65,000	

1 WATT—40¢

100,000Ω	128,000Ω	180,000Ω	470,000Ω	525,000Ω
120,000	130,000	250,000		600,000
125,000	160,000	320,000	522,000	700,000

1 Megohm, 1 Watt, 1%—65¢; 5%—40¢

CERAMIC CONDENSERS

$7.00 per 100

3 mmf	10 mmf	22 mmf	68 mmf	115 mmf
3.44	15	27	75	200
4.7	16	47	82	1000
6.8	18	50	91	1090
8	20	56	100	

PRECISION POTENTIOMETERS

20,000Ω	Muter	314A	$1.70
20,000	GR	314A	2.50
10,000	Muter	471T	2.35
10,000	DJ	292	.95
10,000	GR	371T	2.50
10,000	GR	471A	3.50
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6,000	DJ	260	1.70
6,000	GR	314A	2.50
5,000	Muter	314A	1.70
5,000	DJ	271T	2.00
5,000	GR	314	2.50
2,000	Muter	314A	1.70
2,000	DJ	260	1.70
50	DJ	292	.75
20	GR	301	1.10
12	DJ	292	.75

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X124T2-UTAH, Mkd. 9262 or 9280 .....$1.50

D161310 Western Elec. 50Kc to 4 Mc $2.00

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800 KVA, G.E. No. K 2731, 1 microsecond, 400Ω output, 9,500 V. input, 28,000 V. pk. output $19.50

GE 7557296-250 KVA ¼ microsecond $15.00

SILVER MICAS

10 mmf	125 mmf	370 mmf	540 mmf	.002 mfd
22	150	390	560	.0024
39	180	400	665	.0025
50	200	430	700	.0027
62	240	466	750	.003
68	250	470	800	.0033
68	300	488	820	.0039
100	330	500	.001 mfd	.005
110		510	.0012	.0051
120	360	525	.0013	.0068
			.0015	.01

PRICES OF SILVER MICAS

10 mmf to .001 mfd ..... 10¢

.0012 mfd to .0027 mfd ..... 20¢

.003 mfd to .0068 mfd ..... 50¢

.01 mfd ..... 65¢

Minimum Order, $3.00 **All Orders F.O.B. Phila.**

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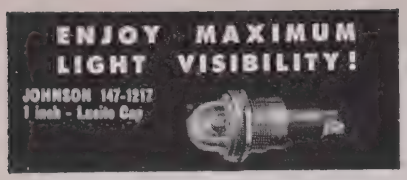

Lucite Cap permits mounting bulb far forward for maximum visibility—especially suitable for neon glow lamps. Fits 1" hole. Has polished chrome bezel. Available in red, amber, opal and clear. Uses NE-45 Neon. No resistor required.

JOHNSON 147-1143 11/16 inch Lucite Cap

Especially suitable for NE-51 neon glow lamp. Soldered terminals. Fits 11/16" hole. Bulb also mounted far forward for maximum visibility. Soldered terminals. Choice of red, amber, opal or clear.

JOHNSON carries in stock a complete line of standard pilot light assemblies to meet every ordinary need. Special assemblies, to meet your most exacting requirements, can be furnished in production quantities on special order. Your inquiries are invited.

JOHNSON
E. F. JOHNSON CO. WASECA, MINN.

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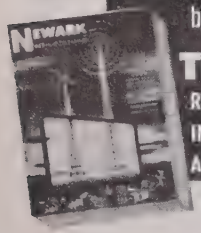

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No matter how tiny the part, how tremendous the system... it's listed in this mammoth catalog... the one easy, satisfactory way to always get top-performing, top-value equipment! The most complete essential reference book for pros, hams, hobbyists, novices, oldtimers... anyone, everyone interested in TV, radio and sound equipment!

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Dept. C23 Please send FREE Newark Catalog to:

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Positions Wanted

ELECTRONIC ENGINEER

B.S.E.E., University of Texas, August 1948, communications major. 2 years experience as Navy electronics technician, partly with guided missiles; 2 years commercial radio servicing; 6 months experience in microwave design. Further details on request. Prefer position in southwest. Box 241 W.

ELECTRONIC ENGINEER

B.S. radio and electronic engineering, June 1949. Married, 3 children. Age 24. Air force communications and radar maintenance officer. 1st class phone license. Prefer west coast. Box 242 W.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

New Binary Scaler

General Electric Co., Syracuse, N.Y., offers a new binary scaler for high-speed counter or nuclear work, known as the 4SN1A1, capable of functioning at speeds up to 200 kc. In applications involving industrial counting, interval timing, and repeat cycling, all will find this new scaler useful because of its plug-in-design and high-speed operation. A 12AT7 tube plugs into the top of the binary scaler, completing the unit. A resolution time of 5 microseconds and output impedance of 27 kilohms are the characteristics of the unit, which fits the standard octal socket. The Specialty Products Div. of the makers will supply full data to interested users.

(Continued on page 57A)

Kahle

ELECTRON TUBE MACHINERY OF ALL TYPES

STANDARD AND SPECIAL DESIGN

We specialize in Equipment and Methods for the Manufacture of

RADIO TUBES
CATHODE RAY TUBES
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INCANDESCENT LAMPS
NEON TUBES
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X-RAY TUBES
GLASS PRODUCTS

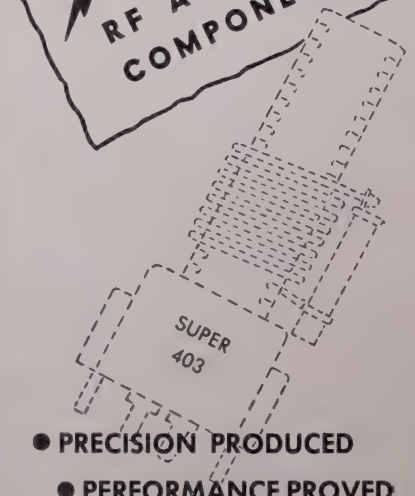
Production or Laboratory Basis

Manufacturers contemplating New Plants or Plant Changes are invited to consult with us.

KAHLE
ENGINEERING COMPANY
1315 SEVENTH STREET
NORTH BERGEN, NEW JERSEY, U.S.A.

NOTE THIS NAME

SUPER RF AUDIO TV COMPONENTS



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SUPER ELECTRIC PRODUCTS CORP.
Pacing Electronic Progress With Ingenuity
1057 Summit Ave., Jersey City 7, N. J.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 56A)

Timer for Audio Program Control

Montgomery Mfg. Co., 549 W. Washington St., Chicago, Ill., have a timer that is applicable to the control of audio installations and wired-music program installations, because of the accuracy with which it can be set.

Units of 2½ minutes or more can be controlled from the timing mechanism, which is small in size, considering the flexibility with which it has been designed. From a single operation to a full week's program can be handled, which will be repeated until the clock is reset for a new program cycle.

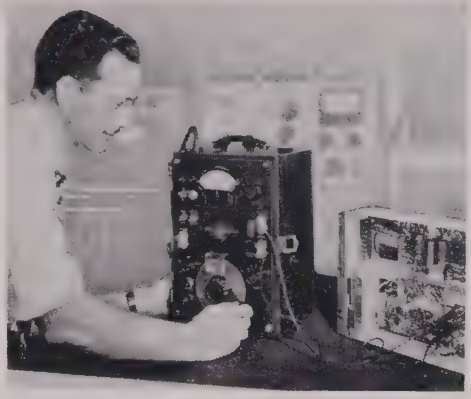
Recent Catalogs

Test Equipment Sales Co., Inc., 216 N. 12th St., Philadelphia, Pa. have offered their bulletin 2610 on the test equipment products of a group of prominent manufacturers. Carefully grouped as to the makers, detailed descriptions enable engineers and purchasing agents to easily select their needs for oscillographic equipment, af and rf signal generators and from a wide selection of meters, both of conventional design, and of the high-sensitivity vacuum-tube-voltmeter variety. Comprehensive combination of data makes this bulletin a valuable file piece.

George J. Maki, Moraga, Calif., has published technical data on his new model RC-55 Frequency Shift Radioteletype Converter. This unit couples to the radio receiver, and through patented circuit configurations converts the narrow shift of frequency used for print or space signals in teletype printers to direct-current operating potentials. Use of pentode discriminator tubes, the incorporation of medium Q circuits, and special biasing arrangements make for stable operation of the decoder. Controls are held to a minimum, but include a milliammeter and electron-ray tube, to give visual indication of the proper functioning of the apparatus in use.

(Continued on page 58A)

Z-ANGLE METER'S
Accuracy—Speed—Simplicity
PLEASES LANGEVIN ENGINEERS



THE Z-ANGLE METER is a modern, self-contained instrument for making quick, accurate measurements of IMPEDANCE and PHASE ANGLE at audio frequencies.

Write today for Bulletins on the Z-Angle Meter, R-F Z-Angle Meter, R-F Oscillator, Precision Variable Resistors, Translatory Variable Resistors, Slide Wire Resistance Boxes and Audio & Super-Sonic Phase Meters.

AUDIO ENGINEERS:

Note This Report From Langevin

"The Langevin Manufacturing Corporation Development Laboratories finds the Z-Angle Meter extremely useful in the determination of transformer impedances. In the manufacture of amplifiers it is often necessary to determine the impedances existing within amplifier stages. Heretofore, these determinations have involved a long drawn out test procedure. The Z-Angle Meter, however, allows readings to be made accurately and quickly."

Their engineers say, ". . . the plate impedence of a resistance coupled triode tube can be determined by taking a reading with the Z-Angle Meter at the output terminals and then extracting the unknown from the mathematical formula for the impedances in parallel. This is only one of the many uses we have found for this instrument."

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LOW ATTEN TYPES	IMPED OHMS	ATTEN db/100ft at 100 Mc/s.	LOADING Kw	O.D."	
A 1	74	1.7	0.11	0.36	
A 2	74	1.3	0.24	0.44	
A 34	73	0.6	1.5	0.88	HIGH POWER FLEXIBLE
LOW CAPAC TYPES	**CAPAC mmf/ft**	**IMPED OHMS**	**ATTEN db/100ft 100 Mc/s**	**O.D"**	
C 1	7.3	150	2.5	0.36	
PC 1	10.2	132	3.1	0.36	PHOTOCELL CABLE
C11	6.3	173	3.2	0.36	
C 2	6.3	171	2.15	0.44	
C 22	5.5	184	2.8	0.44	
C 3	5.4	197	1.9	0.64	
C 33	4.8	220	2.4	0.64	V.L.C. *
C44	4.1	252	2.1	1.03	

* Very Low Capacitance cable

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CONTRACTORS TO H.M. GOVERNMENT
138A CROMWELL ROAD LONDON SW7 ENGLAND
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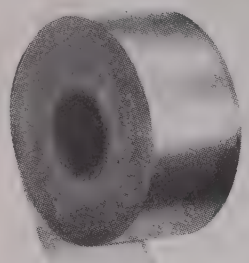

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 57A)

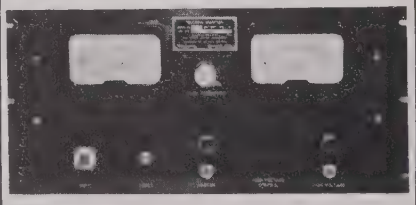
Precision Radiation Instruments, Inc. 1101 N. Paulina Ave., Chicago 22, Ill., has mailed a new catalog descriptive of their portable Geiger-Mueller survey meter finding application in all instances where danger to personnel exists in the field of radiation from isotopes or X-ray radiation. A copy is free, for the asking.

Hammarlund Mfg. Co., 460 W. 34 St., New York 1, N. Y., will add the name of all those who request it to their mailing of a forthcoming new capacitor and component catalog, which is about due to leave the hands of the printer. Detailed drawings of the physical size of all components is included as a help to design and drafting engineers, so that they will be able to determine the physical applications of the new and smaller components which will be available from Hammarlund in the near future.

E. F. Johnson Co., Waseca, Minn., has a new catalog ready for the amateur describing their new series of plug-in swinging-link rf transmitting inductors. It is of interest, too, to the designer of low-powered commercial transmitting installations and laboratory equipment.

(Continued on page 59A)

Neutron and Alpha MONITORS



Neutron Monitor:

A logarithmic count rate meter for use with boron-lined proportional counter for detecting fast neutrons.

Operates on 115 volts—60 cycles; Input sensitivity—3 millivolts, negative; full scale sensitivity—10,000 C/M, 100,000 C/M (when reset switch is depressed); caution light and external alarm gives warning when tolerance exceeded; 600-900 volt counter supply with regulation of 0.01% per percent change in line voltage (90 to 120 volts); input connector (83-IR) on front panel; connections for external recorder (83-22R), external alarm (3-prong female) and ground (binding post) on rear of chassis. Can be supplied with 3000 volt power supply for use with Boron-tri-fluoride tube.

Alpha Monitor: A proportional counter for detecting alphas. Same as Neutron Monitor except for 2500 to 3000 volt counter supply with regulation of 0.01% per percent change in line voltage.

TELEMARK, INC.
79 Prospect St., Stamford, Conn.

NULLI SECUNDUS!

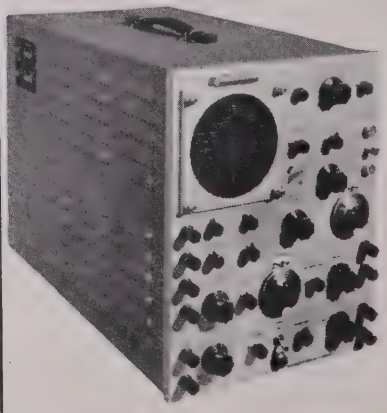
Yes, you'll find upon careful appraisal, thorough investigation and direct comparison that TEKTRONIX instruments are truly **SECOND TO NONE.**

The Tektronix Field Engineering Representative in your area will be pleased to demonstrate either instrument upon request.

Tektronix Type 511-AD Oscilloscope
$845 f.o.b. Portland

Wide Band, Fast Sweeps

The **Type 511-AD,** *with its 10 mc. amplifier, 0.25 microsecond video delay line and sweeps as fast as .1 microsec./cm. is excellent for the observation of pulses and high speed transient phenomena. Sweeps as slow as .01 sec./cm. enable the 511-AD to perform superlatively as a conventional oscilloscope.*



Tektronix Type 512 Oscilloscope
$950 f.o.b. Portland

Direct Coupled, Slow Sweeps

The **Type 512** *with a sensitivity of 5 mv./cm. DC and sweeps as slow as .3 sec./cm. solves many problems confronting workers in the fields where comparatively slow phenomena must be observed. Vertical amplifier bandwidth of 1 mc. and sweeps as fast as 3 microsec./cm. make it an excellent general purpose oscilloscope as well.*

Both Instruments Feature:

- *Direct reading sweep speed dials.*
- *Single, triggered or recurrent sweeps.*
- *Amplitude calibration facilities.*
- *All DC voltages electronically regulated.*
- *Any 20% of normal sweep may be expanded 5 times.*

Phone EA 6197 — *Cables* Tektronix

TEKTRONIX INC.

712 S. E. Hawthorne Blvd.
Portland 14, Oregon

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 58A)

Recent Catalogs

Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena, Calif., have a detailed catalog of their analytical instruments for scientific research and industrial tests. Comprising isotope radiation detectors, electrical computers, and vibration and spectrographic devices, the field covered is wide. A copy will be mailed to interested users who address the company on their corporate stationery.

Enjay Co., Inc., 15 W. 51 St., New York 20, N. Y., has a booklet describing Vistanex (polyisobutylene) as to its processing and compounding. Of interest to the design engineer and those working the plastics, it describes chemical, mechanical, and application details of this new synthetic compound. A copy will be sent to the interested engineer, by addressing the company, which is a division of the Standard Oil Company of New Jersey.

The Aluminum Association of America, 420 Lexington Ave., New York 17, N. Y., has a "Materials & Methods Manual, #35" describing all manner of aluminum alloy castings, considering problems of design, choice of cast, and chemical considerations. This can be had upon request to the association.

Ettco Tool Co., 594 Johnson Ave., Brooklyn 6, N. Y., have a bulletin describing their automatic tapping and threading attachments that fit a drill press and serve to thread and tap small parts. These units are automatic and rapid in operating, working on the sensitive clutch principle, and are easily used by inexperienced operatives. Production engineering staffs will find this story of interest in large-scale factory production operations.

Reliable Electric Co., 3145 Carroll Ave., Chicago 12, Ill., have compiled an extensive looseleaf catalog on their wiring and cable-splicing devices, telephone-line protection equipment, and cable frame termination racks. While not many radio items are included, the engineer working with high-tension equipment, will be interested in the devices enabling cable branching to take place in plant wiring systems, and interbuilding power distribution networks. Separate bulletins or the complete catalog, will be supplied to those interested upon written request, addressed to the attention of E. Freimuth of Reliable Electric.

Fish-Schurman Corp., 230 E. 45 St., New York 17, N. Y., have a bulletin on their F-S Multi-Layer interference films which are useful to the optical engineer pioneering in tricolor television work. This bulletin describes two types of these films, which can either split the beam or transmit it in toto. A copy will be sent gladly upon request.

Hazeltine Electronics Corp., 58-25 Littleneck Parkway, Little Neck, L. I., N. Y. announce Bulletin 14, descriptive of television test equipment of their design

(Continued on page 60A)

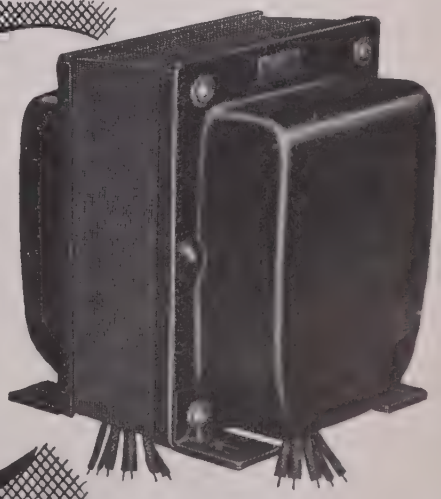
DESIGNING Engineers are learning a new conception of accuracy when they specify one per cent HIGH STABILITY Resistors in their equipment. Where, in the past, other makes of resistors have failed to live up to rigid test specifications, the need for accuracy has not diminished, but is more precise than ever. Welwyn alone, among all makers of resistors, can be relied upon to exceed, not just meet, the stringent specificaions of a really stable component. Over a decade of experience in manufacturing technique and field usages preceded the introduction of this first truly stable 1% resistor to the American Market. Ours are not claims, made on the best we produce, but accurate statements of laboratory-proven tests. A trial in your own equipment will conclusively demonstrate Welwyn HIGH STABILITY Resistors to be superior to all other makes, on every count.

Other Welwyn components comprise Pyromatic Resistors, ranging from 2.5 to 10^{6}MΩ; vitreous enameled wirewound resistors of a superior design and moisture proof construction, including a miniature 3-watt size; and air spaced trimmer capacitors in three popular ranges, with a high ratio of minimum to maximum capacity.

Descriptive literature and price schedules are available, covering these quality components, upon written request.

WELWYN ELECTRONIC COMPONENTS, INC.
234 East 46th Street, New York 17, N.Y.
Murray-Hill 2-2535

PROVIDES BETTER TELEVISION RECEPTION

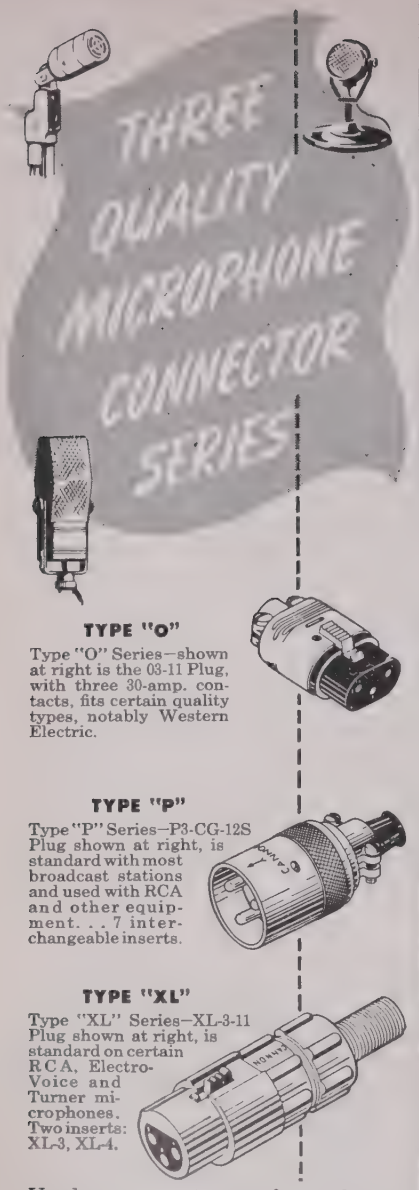


Small, but important features of design and construction make Acme Electric Transformers better performers. For example, cores are riveted as well as bolted, and varnish impregnated to positively eliminate any "hum or buzz." Acme Electric engineers can design a Power Transformer, Filter Reactor, Vertical Sweep Output Transformer, to your exact requirement, from standard parts and assemblies to provide better performance for your set.

The 500 V. A. Acme Electric Television Power transformer, may be the solution to your problem of better set performance.

ACME ELECTRIC CORPORATION • 443 Water St., Cuba, N. Y., U.S.A.

Acme ACME Electric
TRANSFORMERS



TYPE "O"

Type "O" Series—shown at right is the 03-11 Plug, with three 30-amp. contacts, fits certain quality types, notably Western Electric.

TYPE "P"

Type "P" Series—P3-CG-12S Plug shown at right, is standard with most broadcast stations and used with RCA and other equipment. . . 7 interchangeable inserts.

TYPE "XL"

Type "XL" Series—XL-3-11 Plug shown at right, is standard on certain RCA, Electro-Voice and Turner microphones. Two inserts: XL-3, XL-4.

Used on many types of sound and communication equipment in addition to microphone, *Cannon Plugs* are recognized by engineers, sound men and hams as the quality fittings in the field. Over a period of years various improvements have been made in insulating materials, shell design, material and clamp construction.

Available through many parts jobbers in the U. S. A. . . In *Louisville:* Peerless Electronic Equipment Co. In *Flint:* Shand Radio Specialties. In *Syracuse:* Morris Dist. Co. In *Toledo:* Warren Radio. In *Norfolk:* Radio Supply Co.

Bulletin PO-248 covers all the engineering data on the above 3 series; RJC-2 the prices; CED-8 Sheet lists jobbers. For copies address Department C-377.

SINCE 1915

CANNON ELECTRIC

Development Company

3209 HUMBOLDT ST., LOS ANGELES 31, CALIF.

IN CANADA—CANNON ELECTRIC CO., LTD.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 59A)

Recent Catalogs

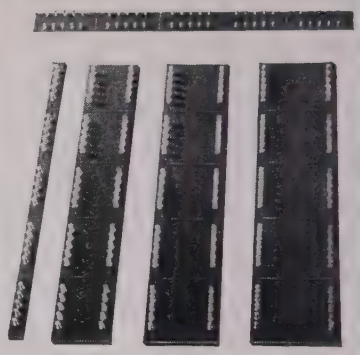
and manufacture. Interested engineers will find this bulletin to contain specific data on 10 more-detailed engineering data reports on the equipment under consideration, copies of which will be sent upon written request to the company. The line is so complete that it affords a complete laboratory installation for production and service testing of video equipment. Centralized generating apparatus, with remote-test-position equipment for several simultaneous test and alignment operations, are the features incorporated in this line of precision devices.

Radio Corporation of America, Harrison, N. J., have issued data bulletins on their two latest additions to the klystron line of uhf tubes. the 2K26 and 2K56. They are single-resonator reflex-type tubes, used mainly as local oscillators in microwave receiving equipment, as frequency-modulated sources in low-powered transmitters, or as pulsed oscillators for response-testing equipment. They are identical in appearance and in power output, (100 milliwatts) but differ in the portion of the spectrum in which they operate.

Amperex Electronic Corp., 25 Washington St., Brooklyn 1, New York, announce a comprehensive 296-page catalogue of their complete line of electronic tubes, The communication, industrial electromedical, and amateur fields are all served by the products of Amperex, described in this bulletin. Each section has a descriptive introduction, preceding the detailed listing of the individual characteristics of all tubes and vacuum capacitors made by this firm. So complete is its form of presentation that it forms a

(Continued on page 61A)

Save Time...Speed Assembly with CTC ALL-SET Boards!



On the assembly line and in the laboratory, CTC *ALL-SET* Boards are valuable time-savers.

With Type 1558 Turret Lugs, a new board now offers mounting for miniature components. 1 1/16″ wide, 3/32″ thick, only. (Type X1401E.)

With Type 1724 Turret Lugs, boards come in four widths: ½″, 2″, 2½″, 3″ — in 3/32″, ⅛″, 3/16″ thicknesses.

With the addition of the new miniature board, CTC *ALL-SET* Boards now cover the entire range of components.

All boards are of laminated phenolic, in five-section units, scribed for easy separation. Each section drilled for 14 lugs. Lugs solidly swaged into precise position . . . whole board ready for your assembly line.

SPECIAL PROBLEMS

Custom-built boards are a specialty with CTC. We're equipped to handle many types of materials including the latest types of glass laminates . . . many types of jobs requiring special tools . . . and all types of work to government specifications. Why not drop us a line about *your* problem? No obligation, of course.

CAMBRIDGE THERMIONIC CORPORATION

456 Concord Avenue, Cambridge 38, Mass.

Made in almost all ductile metals and alloys; or we will draw wire from your own metals.

Your inquiry, with engineering specifications is invited.

SIGMUND COHN CORP.
44 GOLD ST. NEW YORK
SINCE 1901

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 60A)

designing reference work. The Amperex organization will provide a copy to those who apply in writing, stating their business connection on their letterhead.

Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill., has just published their 1949 catalogue of radio and electronic components and completed communication units. In 180 pages they have listed the products of the country's leading manufacturers in a compact form, for ready reference by the buyer, design engineer, sound installation man, or amateur. Copies may be had free, for the asking.

National Carbon Co., 30 E. 42 St., New York, N. Y. has announced a new Eveready 1005-E primary battery for hearing-aid use. The possibilities of this new air-cell have not yet been fully explored, in the radio and electronic field, aside from the hearing-aid application. The cell operates on a principle different from the usual "A" battery (Leclanche type), and features a stable output voltage over 90% of its useful service life, contrasted to the usual flashlight cell. They have published descriptive material and performance graphs, pictorially showing the results, when submitted to standardized ASA testing procedures. Copies of this report are available to test engineers, upon request, who will find this cell applicable to many miniature instruments in the industry.

Weller Manufacturing Co., Easton, Pa., have just released a comprehensive catalogue bulletin on their line of instant-heating soldering guns. Industry acceptance of these versatile units has caused many new models to be added to the line, to meet the demand from the industry. Copies of the bulletin can be had for the asking.

High-Voltage Cathode-Ray Oscillograph

The type 248-A oscillograph can now be operated at accelerating potentials up to 14,000 volts without modification, according to its manufacturer **Allen B. DuMont Labs., Inc.,** 1000 Main Ave., Clifton, N. J.

Merely by the addition of a suitable external power supply, such as the DuMont type 263-B, the accelerating potential applied to the 248-A may be increased from 2,000 or 4,000 volts, applied internally, to 14,000 volts.

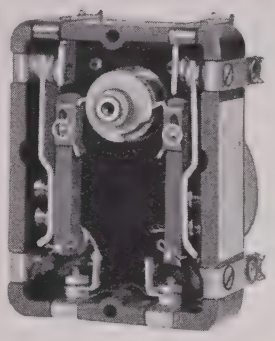
This increase is accomplished by the incorporation of the type 5RP-A high-voltage cathode-ray tube.

Deflection sensitivity changes result from the higher accelerating potential. The new deflection factor at 14,000 volts, using type 263-B power supply is 0.15 rms volt per inch.

Photographic writing rates of the order of 69 inches per microsecond can now be recorded when using the increased accelerating potential.

(Continued on page 62A)

Cramer
TIME DELAY RELAY



APPLICATION

Designed specifically for use in radio or electronic devices, Cramer synchronous Type TC Time Delay Relays provide a fixed time delay between the energization of the timer and the opening or closing of an auxiliary circuit. Provision is made for momentarily delaying the restoration of the auxiliary circuit when the timer is de-energized.

ADJUSTABILITY

Available as 45 second timer, adjustable from 2.5 seconds . . . as 60 second timer, adjustable from 4 seconds.

CIRCUIT ARRANGEMENT

Types TC-45S and TC-60S — single pole, normally open, normally closed or double throw; double throw, normally open, normally closed or double throw; or any combinations of these poles or throws.

Types TC-2M through TC-5M — single pole, normally open, normally closed.

TIME RANGES

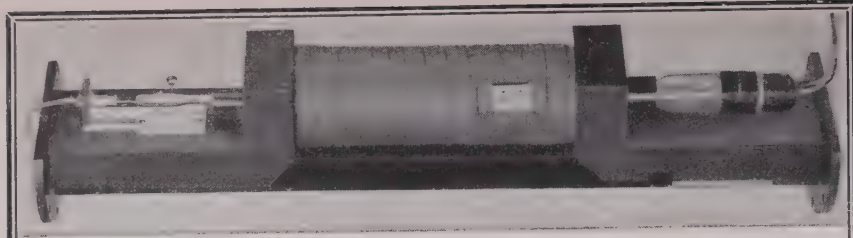
TIME RANGE	POLES	SETTING	TYPE
2.5 to 45 sec.	S.P.S.T.	Adjustable	TC-45S
4 to 60 sec.	S.P.S.T.	Adjustable	TC-60S
2 min.	S.P.S.T.	Non-Adj.	TC-2M
3 min.	S.P.S.T.	Non-Adj.	TC-3M
4 min.	S.P.S.T.	Non-Adj.	TC-4M
5 min.	S.P.S.T.	Non-Adj.	TC-5M

For complete data write for Bulletin No. 900C

THE R. W. CRAMER COMPANY, INC.
Box #12, Centerbrook, Conn.

INTERVAL – CYCLE – IMPULSE – PERCENTAGE TIMERS
RUNNING TIME METERS – GEARED SYNCHRONOUS MOTORS

3CR49



TRAVELING WAVE AMPLIFIERS

FOR LABORATORY AND EXPERIMENTAL USE

Operates in the vicinity of S-Band

SPECIFICATIONS

BANDWIDTH: 2700-3300 mc, flat to ± 3 db

MODULATION LINEARITY: Linear up to 0.1 watt output

INPUT-OUTPUT CONNECTIONS: 1½"x3" S-Band wave guide

BEAM VOLTAGE: 2500 maximum

GAIN AT 3000 MC: 18 db or greater

BEAM CURRENT: 20 ma maximum

Focusing coils can be supplied over a reasonable range of voltages and currents

Klystrons, Traveling Wave and other Microwave Tubes designed and developed by VARIAN engineers to your specifications

VARIAN ASSOCIATES

(Telephone: Redwood City—EMerson 8-0119)

99 WASHINGTON STREET SAN CARLOS, CALIFORNIA

S·S·White MOLDED RESISTORS

The "All-Weather" Resistors

ARE USED IN THIS ULTRA SENSITIVE ELECTRONIC PHOTOMETER

In this instrument—designed for measurement of very low light values—S.S.White Resistors serve as the grid resistance in the all-important high-gain D.C. amplifier circuit. The manufacturer, Photovolt Corp., New York, N.Y., reports that the resistors "work very satisfactorily"—which checks with the experience of the many other electronic equipment manufacturers who use S.S.White resistors.

S.S.WHITE RESISTORS

are of particular interest to all who need resistors with inherent *low noise level* and *good stability* in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS
STANDARD RANGE
1000 OHMS to 9 MEGOHMS

WRITE FOR BULLETIN 4505

It gives essential data about S.S.White Resistors, including construction, characteristics, dimensions, etc. Copy with price list on request.

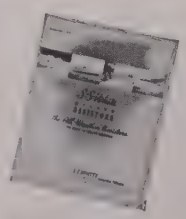


Photo courtesy of Photovolt Corp., New York, N.Y.

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. GR, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AND ACCESSORIES
MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

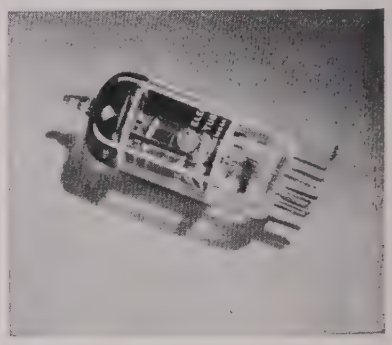
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 61A)

Miniature Tube for Industrial Applications

A new 7-pin miniature electronic tube, type GL-5610, to be used for industrial purposes where small size is a factor, has been announced by the **Tube Division, General Electric Co.,** Electronics Park, Syracuse, N. Y.



This tube may be used to operate a relay in a circuit for heating control or many other industrial operations.

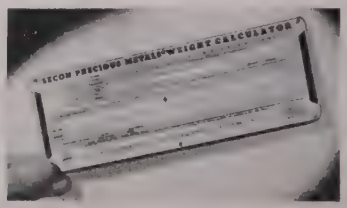
Under maximum ratings the plate voltage is 300 volts, with a plate dissipation of 3.0 watts.

Its typical operation characteristics include the following: heater voltage, 6.3 volts; plate current, 17 ma; plate resistance, 3500 ohms.

The physical dimensions of the GL-5610 are: diameter, $\frac{3}{4}''$; over-all length, $2\frac{1}{8}''$; seated height, $1\frac{7}{8}''$.

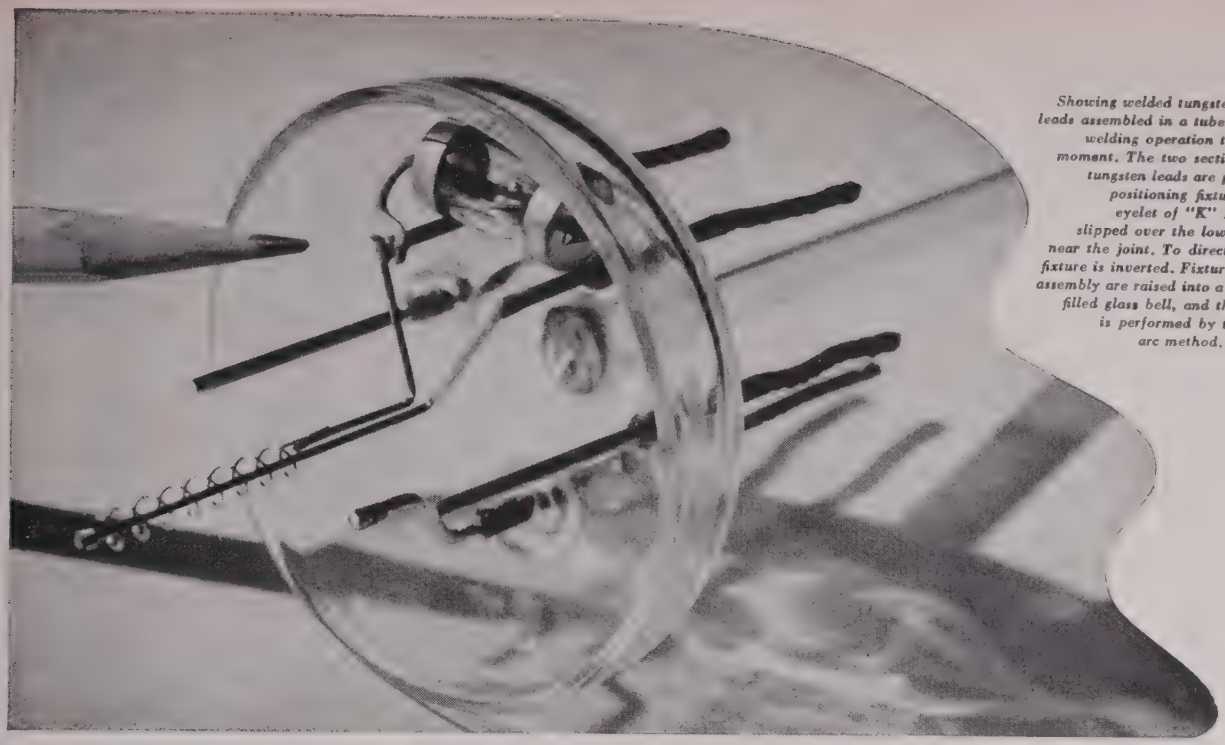
Precious-Metals Weight Calculator

A new firm, **Secon Metals Corp.,** 228 E. 45 St., New York 17, N. Y., engaging in the sale and processing of platinum and other nonferrous metals manufactured in the forms of sheet, wire, and foil for industrial application, as well as custom forms for particular needs, is now offering a precious-metals weight calculator.



This calculator rapidly computes the weight of platinum, palladium, gold, and silver in the forms of sheet, wire, tubing, and circles. Answers are computed in Troy ounces. It will also determine the weight per foot and number of feet per Troy ounce of wire.

This is accomplished by a calculator which operates on the slide-rule principle. One or two settings and the problem is solved.



Showing welded tungsten filament leads assembled in a tube base. The welding operation takes but a moment. The two sections of the tungsten leads are placed in a positioning fixture. A tiny eyelet of "K" MONEL is slipped over the lower section, near the joint. To direct flow, the fixture is inverted. Fixture and lead assembly are raised into a hydrogen-filled glass bell, and the welding is performed by the carbon arc method.

How a problem in welding tungsten was solved

VHF beam tetrode tube, manufactured by the United Electronics Co., Newark, N.J. ▶

While improving the design of their VHF beam tetrodes, the United Electronics Company ran into a difficult technical problem.

In their tube types 5D22 and 4D21, tungsten filament leads are brought out to conventional base prongs. However, to locate the filament at the center of the structure, the two internal filament leads had to be sharply offset. It was necessary, also, that the leads be accurately aligned with the base outlet holes, to eliminate stresses which might crack the glass envelope when the tube was put in service.

Bending the tungsten leads to shape proved too inaccurate a method. So it was decided to make the leads in two sections — one straight, and one bent — welding them together in precision positioning fixtures.

This method of assembly proved satisfactory, but difficulty was immediately encountered in finding a suitable joining metal.

Several metals were tried without success. Either they failed to "wet" the tungsten, or caused it to embrittle.

Finally, United Electronics Company engineers tried "K"* MONEL — *and it proved to be the answer to their problem.*

"K" MONEL "wet" the tungsten satisfactorily; flowed well; made strong, smooth joints; was resistant to oxidation and corrosion. In addition, "K" MONEL's melting point was safely above both exhausting and tube operating temperatures.

This is but one of countless ways that Nickel and its alloys are helping industry to build better products. If you have a problem in metal selection, get to know the family of INCO Nickel Alloys with their unique combination of properties. Our technical department is always ready to assist you. Write for "66 Practical Ideas for Metal Problems in Electrical Products."

The International Nickel Company, Inc.

67 Wall Street • New York 5, N. Y.

EMBLEM OF SERVICE

NICKEL INCO TRADE MARK ALLOYS

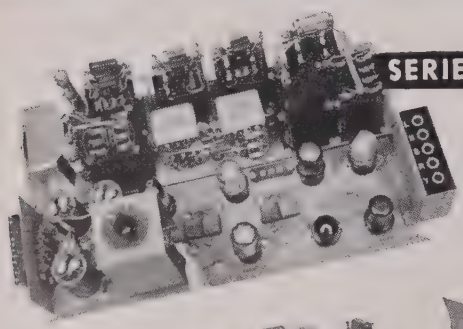
MONEL* • "K"* MONEL • "S"* MONEL • "R"* MONEL • "KR"* MONEL • INCONEL* • NICKEL • "L"* NICKEL • "Z"* NICKEL

*Reg. U. S. Pat. Off.

ADC Quality Wins Again

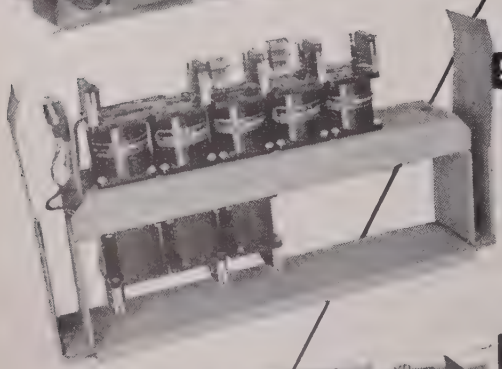
ADC

An important part of WESTERN UNION'S nation-wide plant mechanization program is the new Type 20 FM Carrier Channel Terminal equipment. Designed to provide telegraph message channels for the interconnection of telegraph offices, this new equipment was ordered in large quantities from the Radio Corporation of America in the fall of 1946. **ADC** was chosen to provide the transformers and inductors—over 85,000 coil assemblies were produced by **ADC** under rigid specifications and on individual test inspection only 14 were rejected.



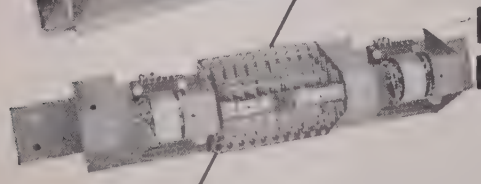
SERIES 550-50 TRANSCEIVER

When Western Union recently ordered additional quantities of this equipment, Radio Corporation of America again won the contract award and **ADC** was again chosen for the transformers—inductors.



SERIES 550-50 TUNER

The accompanying photographs show three of the principal components of Western Union's Type 20 FM Carrier Channel Terminal equipment.



SERIES 2-A CARRIER COUPLER

Series 550-50—Tuner
Series 550-50 } Transceiver
Series 2-A } Carrier Coupler

This proven dependability of **ADC** QUALITY PRODUCTION is available to *you* . . . submit your specifications or problems for prompt attention.

ADC Audio DEVELOPMENT CO
Audio Develops the Finest
2855 13th AVE. SOUTH · MINNEAPOLIS 7, MINN.

BALTIMORE

"Narrow-Band Automatic Radio Compass," by K. F. Umpleby and D. M. Heller, Bendix Radio Division; January 25, 1949.

CINCINNATI

"Printed Electronic Circuits," by R. L. Henry National Bureau of Standards; January 18, 1949.

COLUMBUS

"Antenna for Television," by D. C. Cleckner and A. Joost, Antenna Research Laboratories, Inc.; January 12, 1949.

"Electric Coil and Insulation Manufacturing," by D. Stafford, National Electric Coil Company; January 21, 1949.

CONNECTICUT VALLEY

"Transitors," by J. N. Shive, Bell Telephone Laboratories; January 20, 1949.

DALLAS-FORT WORTH

Election of Officers; January 11, 1949.

DAYTON

"The Electron Wave Tube," by A. V. Haeff, Naval Research Laboratory; February 10, 1949.

DETROIT

"Applications of Subminiature Tubes," by R. K. McClintock, Sylvania Electric Products Inc.; January 21, 1949.

LONDON (Ontario)

"Sound Waves, Their Properties and Their Uses," by T. D. Northwood, National Research Council; January 14, 1949.

LOS ANGELES

"A New Long-Playing Disk Recording System," by C. A. Boggs, Columbia Records, Inc.; December 14, 1948.

"Double Stream Amplifier," by W. B. Hebenstreit, Hughes Aircraft; January 18, 1949.

"Analogue Computer for Linear Antenna Arrays," by T. T. Taylor, Hughes Aircraft; January 18, 1949.

MONTREAL

"The Design of FM Equipment for the 160-Mc Band," by F. H. Margolick, Canadian Marconi Company; January 19, 1949.

"Engineers and Canadian Labor Legislation," by F. S. Howes, McGill University; February 8, 1949.

"GCA—Ground-Controlled Approach," by W. E. Ekblaw, Jr., Gilfillan Brothers; February 8, 1949.

NEW MEXICO

"Phase Shift Networks in Single Sideband Transmission," by R. Hoffman, United States Army; January 21, 1949.

NORTH CAROLINA-VIRGINIA

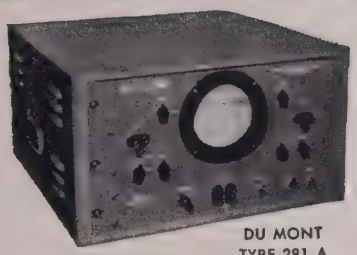
"Raydist," by C. E. Hastings, Hastings Instrument Company; October 15, 1948.

"Electrical Network Analyzers," by K. R. Spangenburg, Naval Research Laboratory; November 19, 1948.

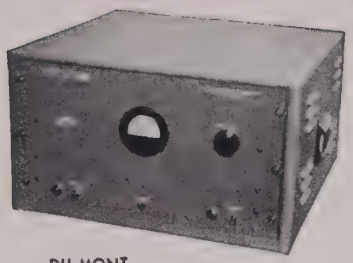
(Continued on page 36A)

THE RIGHT START
is a DUMONT oscillograph!

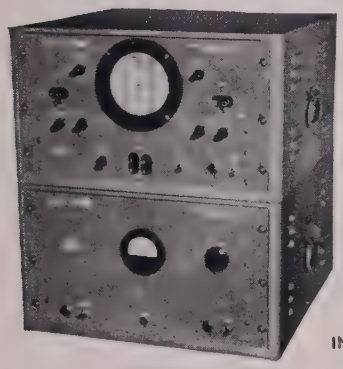
First of a series designed to show the many combinations of Du Mont cathode-ray instruments available for meeting every oscillographic problem.



DU MONT
TYPE 281-A



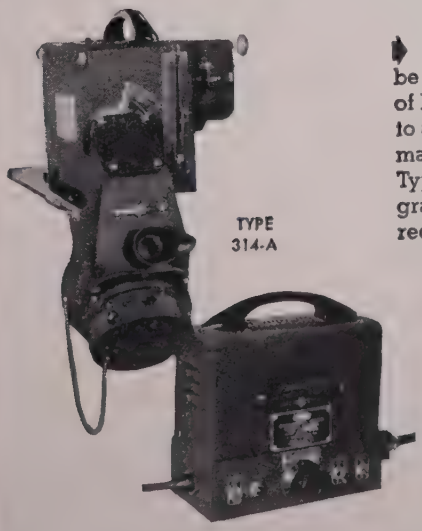
DU MONT
TYPE 286-A



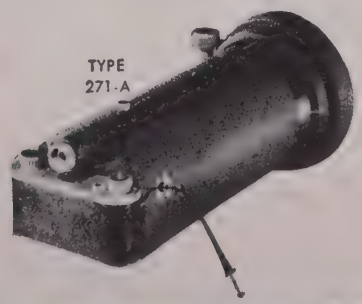
IN COMBINATION

Specifically designed to utilize the outstanding capabilities of the Du Mont Type 5RP-A Cathode-ray Tube, the Type 281-A Cathode-ray Indicator has proved particularly well suited for high-tension studies such as surge testing of power-distribution transformers, lightning arresters and cables, or the study of discharges such as lightning. This instrument also has many applications in the diversified field of nuclear physics.

The capabilities of the Du Mont Type 281-A are further increased by the addition of the Du Mont Type 286-A High-voltage Power Supply. Thus with an extra 25,000 volts accelerating potential, the Type 281-A becomes probably the fastest writing and brightest oscillograph in the world. At a total accelerating potential of 29,000 volts, this combination permits writing rates in excess of 400 inches per micro-second.



TYPE
314-A



TYPE
271-A

A still further combination may be had by means of other elements of Du Mont Oscillography, whereby to achieve all the advantages of permanent oscillograph recording. The Types 314-A and/or 271-A Oscillograph-record Cameras assure lasting records of all traces displayed on the screen of the cathode-ray tube. The very fast writing-rates of the Type 5RP-A Cathode-ray Tube in the above combination may be easily and simply photographed for repeated reference. The Type 314-A affords either continuous-motion or single-image photography. The Type 271-A provides single-image photography only. Both cameras are readily mounted.

Tube Type 5RP-A and all Du Mont cathode-ray tubes, may be purchased separately

Consult us about your oscillographic needs. Equipment demonstration arranged—no obligation.

©ALLEN B DU MONT LABORATORIES, INC.

DUMONT *for Oscillography*

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U.S.A.

INSTRUMENTS
that STAY ACCURATE

Soft iron pole pieces and full bridge construction are only two of the design and production superiorities which have made the SIMPSON name synonymous with perfection in panel meters.

Whatever your technical problems are the SIMPSON Laboratories will help you work them out.

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CHICAGO 44, ILLINOIS

In Canada: Bach-Simpson, Ltd., London, Ont.

SECTION MEETINGS

(Continued from page 34A)

OTTAWA

"The Technique of Television Sound," by R. M. Tanner, Northern Electric Company Ltd.; January 13, 1949.

"Telephone and Telegraph Multiplex on VHF Circuits," by C. B. Fisher, Radio Engineering Products Ltd.; February 3, 1949.

PHILADELPHIA

"Present and Future Trends in Television Receivers," by D. G. Fink, *Electronics;* February 2, 1949.

ROCHESTER

"Radio Propagation above 100 Megacycles," by P. E. Lannan, Stromberg-Carlson Company; January 20, 1949.

SALT LAKE

"Brains, Computing Machines, and Electronics," by L. A. Woodbury, University of Utah Medical School; January 24, 1949.

SAN FRANCISCO

"The Engineer's Role in International Conferences," by R. V. Howard, National Association of Broadcasters; January 5, 1949.

"Engineering Research in the Development of Western Industry," by J. E. Hobson, Stanford University Research Institute; January 27, 1949.

"A Carnival of Measurements," by J. M. Whittenton, General Electric Company; January 31, 1949.

SYRACUSE

"New Developments," by W. Hausz, J. F. McAllister, and R. F. Shea, General Electric Company; January 6, 1949.

"An Evaluation of the Application of New and Old Techniques to the Improvement of Magnetic Recording Systems," by L. C. Holmes, Stromberg-Carlson, Company; February 3, 1949.

TOLEDO

"Technical Advances in the Reproduction of Motion Picture Sound," by H. L. Neuert, Altec Service Corporation; January 17, 1949.

"House of Magic," by W. Hoverman and R. Verbiliss, General Electric Company; February 7, 1949.

TWIN CITIES

"The Microwave Dielectrometer," by D. G. Jelatis, Central Research Laboratories, Inc.; January 4, 1949.

SUBSECTIONS

AMARILLO-LUBBOCK

"WBAP-TV Television Installation," by C. E. Houston, Texas Technical University; January 18, 1949.

Election of Officers; January 18, 1949.

HAMILTON

"Modern B. C. Directive Arrays," by B. de F. Bayly, Bayly Engineering Company; January 17, 1949.

NORTHERN NEW JERSEY

"Broad-Band Microwave Lenses," by W. E. Kock, Bell Telephone Laboratories, Inc.; January 19, 1949.

"Broad-Band Transmission System," by S. Hopfer, Polytechnic Research and Development Corporation; January 19, 1949.

66-G

Here's the Recorder You asked for!

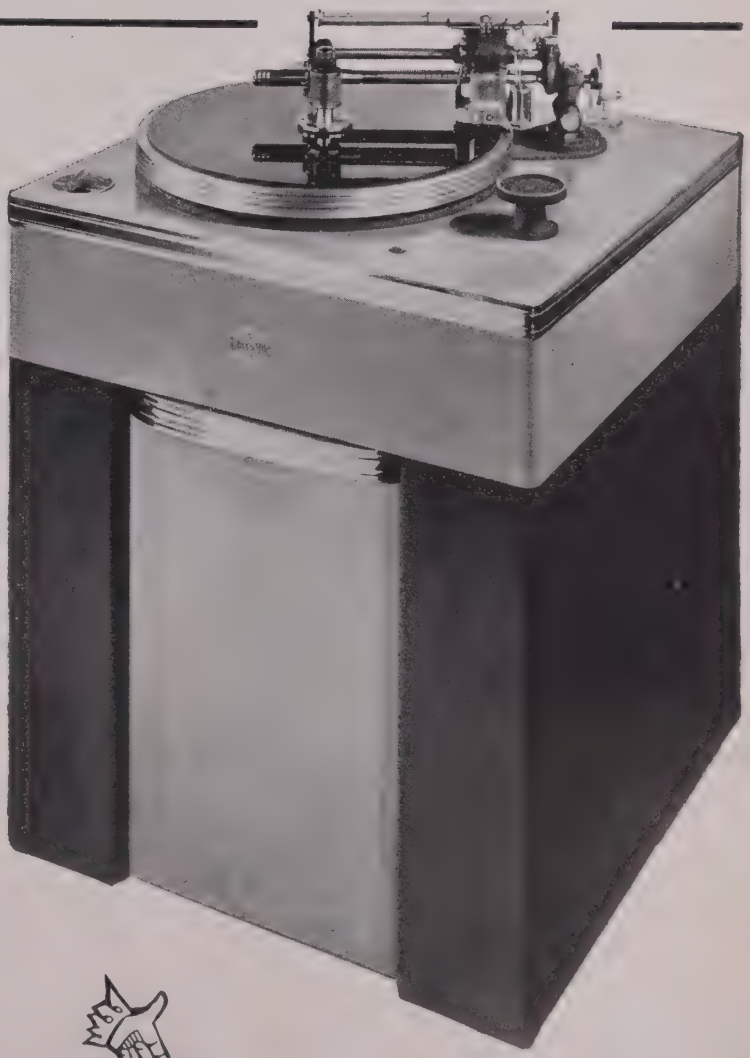
The best features of Presto's dual motor gear drive *with* the overhead mechanism and turntable of the famous Presto 6-N.

YES, engineers have often asked us for a compact, economical yet high-quality recorder. Now you may have it in the Presto 66-G for standard and microgroove recording.

Here is a unit ideally suited and priced for the typical broadcast station or large transcription manufacturer. List price, Standard Model, *$996!* ($70 additional for microgroove.)

Here's perfection in total speed regulation and very low mechanical disturbance, thanks to the standard Presto dual motor gear drive. Here's high-quality recording, too, for the 66-G, of course, includes the Presto 1-D cutting head.

You'll find 66-G equal to the most exacting recording tasks when used with suitable amplifiers such as Presto 92-A recording amplifier and 41-A limiter amplifier.



FOR HIGHEST FIDELITY . . . IT'S PRESTO DISCS

Microgroove, even more than standard recording, demands a perfect disc. The answer is Presto. For, sixteen years ago, Presto made the *first* lacquer-coated discs . . . and today Presto discs are *first* in quality.

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READY NOW: Magnetic Tape Recorder

You probably saw Presto's new superquality magnetic tape recorder at the I.R.E. Show. If not, be sure to see it in Presto's room at the N.A.B. Convention in Chicago.

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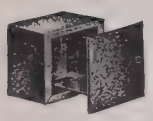
WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT AND DISCS

LET US SOLVE YOUR HOUSING PROBLEM!

BUD announces a complete line of SHEET METAL HOUSINGS for equipment using MINIATURE TUBES

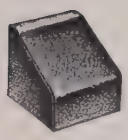
BUD MINIATURE UTILITY CABINETS *with attached Chassis*



Filling a long wanted need for a small cabinet with a chassis attached to the front panel, these cabinets are indispensable when building electronic devices using miniature tubes. Front and rear panels are removable and fastened with self-tapping screws, permitting easy accessibility. Especially useful for HF converters, television amplifiers and power supplies. Finished in black wrinkle.

Cat. No.	Height	Width	Depth	CHASSIS SIZE			Dealer Cost
C-1793	4″	4″	2″	1″	3⅛″	1⅞″	$ .95
C-1794	4″	5″	3″	1″	4⅛″	2⅞″	1.05
C-1795	5″	4″	3″	1¼″	3⅛″	2⅞″	1.05
C-1796	6″	5″	4″	1¾″	4⅛″	3⅞″	1.15
C-1797	5″	6″	4″	1¼″	5⅛″	3⅞″	1.15
C-1798	6″	6″	6″	1¾″	4⅞″	5⅞″	1.20

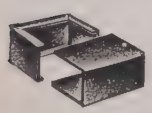
BUD SLOPING PANEL UTILITY BOX



A compact, sloping panel cabinet, providing a streamlined appearance and enough space to house conveniently a 2 or 3 miniature tube amplifier or gadget. A ⅜″ flange around the rear opening of the cabinet provides a convenient back cover mounting. Designed to accommodate a Bud miniature chassis. Finished in black wrinkle.

Cat. No.	Height	Width	Depth	Use Chassis No.	Dealer Cost
C-1602	4″	4″	4¼″	CB-1617	$1.10
C-1603	4″	5″	4¼″	CB-1618	1.20
C-1604	4″	6″	4¼″	CB-1619	1.30
C-1605	4″	7″	4¼″	CB-1620	1.50

BUD HANDY BOXES



Something new in box design permits a large number of small components to be *easily* wired or serviced. The cover is held by 4 self-tapping screws. Black wrinkle finish.

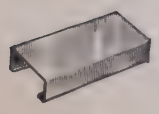
Cat. No.	Height	Width	Depth	Dealer Cost
HB-1621	2¼″	4¼″	1½″	$ .90
HB-1622	2″	4″	2¾″	1.00

BUD MINIATURE AMPLIFIER FOUNDATION

With the increased use of miniature tubes, smaller cabinets can be used when designing a compact amplifier. This amplifier foundation was designed expressly for this purpose. The chassis is a 5″ x 7″ x 2″. The cover is made of perforated metal. A streamlined handle makes this cabinet portable. Finished in black wrinkle.

Cat. No.	Height	Depth	Width	Chassis Height	Dealer Cost
CA-1754	6″	7″	5″	2″	$3.00

BUD ALUMINUM MINIATURE CHASSIS



These small, open end aluminum chassis are just the thing for miniature tube applications or sub-assemblies. Made of hard aluminum with ¼″ flange on bottom, allowing the chassis to be fastened down or a bottom plate to be attached. Extremely useful for small receivers, outboard uses, such as narrow band FM adapters or any use where space is limited. Finish is etched aluminum.

Cat. No.	Depth	Width	Height	Fits Cabinet No.	Dealer Cost
CB-1623	2⅝″	2¾″	1¼″	C-1784	$ .30
CB-1624	1¾″	3½″	1″	CU-883	.33
CB-1625	3½″	4½″	2″	C-1788	.36
CB-1626	2¾″	4⅛″	1″	CU-728	.36
CB-1627	3¾″	4½″	1½″	CU-729	.36
CB-1628	3″	6⅛″	1⅛″	C-1785	.42
CB-1629	5¾″	4⅞″	1½″	CU-1098	.45
CB-1617	4″	3½″	1″	C-1602	.36
CB-1618	4″	4½″	1″	C-1603	.39
CB-1619	4″	5½″	1″	C-1604	.42
CB-1620	4″	6⅛″	1″	C-1605	.45

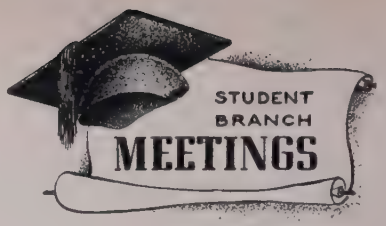
PRICES ARE HIGHER WEST OF THE MISSISSIPPI RIVER

We welcome the opportunity of quoting on special sheet metal items in production run quantities.

BUD — *The mark of perfection*

BUD RADIO, INC.

2110 East 55th Street — Cleveland, Ohio



UNIVERSITY OF CALIFORNIA, IRE—AIEE BRANCH

Election of Officers; January 31, 1949.

UNIVERSITY OF FLORIDA, IRE—AIEE BRANCH

"A Generator for Predetermined Wave Forms," by J. D. Wells, Student, University of Florida; February 8, 1949.

IOWA STATE COLLEGE, IRE—AIEE BRANCH

"My Trip to Mexico," by W. L. Cassell, Iowa State College; January 19, 1949.

STATE UNIVERSITY OF IOWA, IRE BRANCH

"Student Talks," by T. Babcock and E. L. Jesse, Students, State University of Iowa; January 19, 1949.

Election of Officers; January 25, 1949.

"Microwaves in Telephony," by C. D. Peebler, Northwestern Bell Telephone Company; February 9, 1949.

LAFAYETTE COLLEGE, IRE-AIEE BRANCH

"Tesla Coils," by R. W. Karcher, Student, Lafayette College; February 10, 1949.

"Little Known Facts in the History of Electricity Up to 1866," by F. Blanchard, Lafayette College; February 10, 1949.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

Election of Officers; January 12, 1949.

MISSOURI SCHOOL OF MINES, IRE-AIEE BRANCH

"Construction of an FM Broadcasting Station," by W. R. Chapin and R. Nickles, Station KWDG; February 2, 1949.

NEW YORK UNIVERSITY, IRE BRANCH

"Color Television," by G. E. Anner, New York University Faculty; January 20, 1949.

NORTH CAROLINA STATE COLLEGE, IRE BRANCH

"Telemetering in Aeronautical Research," by C. A. Taylor, Langley Memorial Aeronautical Laboratory; February 16, 1949.

"Experimental Functions as Applied to Electrical Engineering," by J. W. Cell, North Carolina State College; January 26, 1949.

NORTHWESTERN UNIVERSITY, I.R.E.-AIEE BRANCH

Election of Officers; January 11, 1949.

"Careers in Power Utilities," by M. C. Kimberly, Commonwealth Edison Company; January 25, 1949.

OREGON STATE COLLEGE, IRE-AIEE BRANCH

"High-Voltage Insulators," by C. R. Kingsbury, Ohio Brass Company; January 27, 1949.

PURDUE UNIVERSITY, IRE BRANCH

"Intercarrier Sound Systems for Television," by S. W. Seeley, Radio Corporation of America; January 28, 1949.

RUTGERS UNIVERSITY, IRE-AIEE BRANCH

"Advantages of Prize Paper Competition," by P. S. Creager, Rutgers University; February 8, 1949.

THE UNIVERSITY OF TENNESSEE, IRE BRANCH

"High-Fidelity Audio Systems," by C. M McCracken, University of Tennessee Faculty; January 18, 1949.

"Your Telephone Voice of the Future," by L. H. Calloway, Southern Bell Telephone and Telegraph Company; February 1, 1949.

UTAH STATE AGRICULTURAL COLLEGE, IRE BRANCH

"The Electron Microscope," by G. Cochran, Utah State Agricultural College; February 9, 1949.

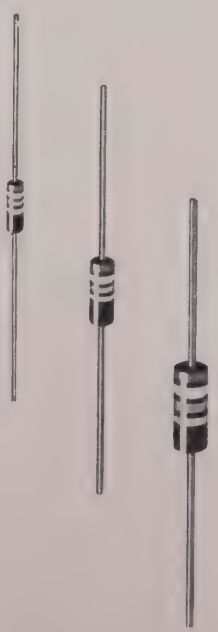
A NEW ADDITION TO THE ALLEN-BRADLEY PLANT FOR PRODUCING A-B FIXED AND ADJUSTABLE RESISTORS

A REPORT to the Radio Industry about Allen-Bradley Radio Resistors

Radio manufacturers have discovered that fixed resistors of run-of-mine quality will not meet the requirements of television circuits.

This situation has, overnight, created an unprecedented demand for the top quality and stability found in Allen-Bradley fixed resistors. In spite of weekly shipments of many millions of Bradleyunits in ½-watt, 1-watt, and 2-watt ratings, the current demand still far exceeds the capacity of the Allen-Bradley radio resistor department . . . and our customers are unhappy with our resistor deliveries.

But a large addition to the Allen-Bradley factory is under way. Much additional resistor production machinery is under construction. However, it will take time before these facilities will be ready for the increased production of Bradleyunits.



Meantime, Allen-Bradley is working twenty-four hours per day—seven days per week—to produce the maximum output of Bradleyunits. It is physically impossible to do more at this time.

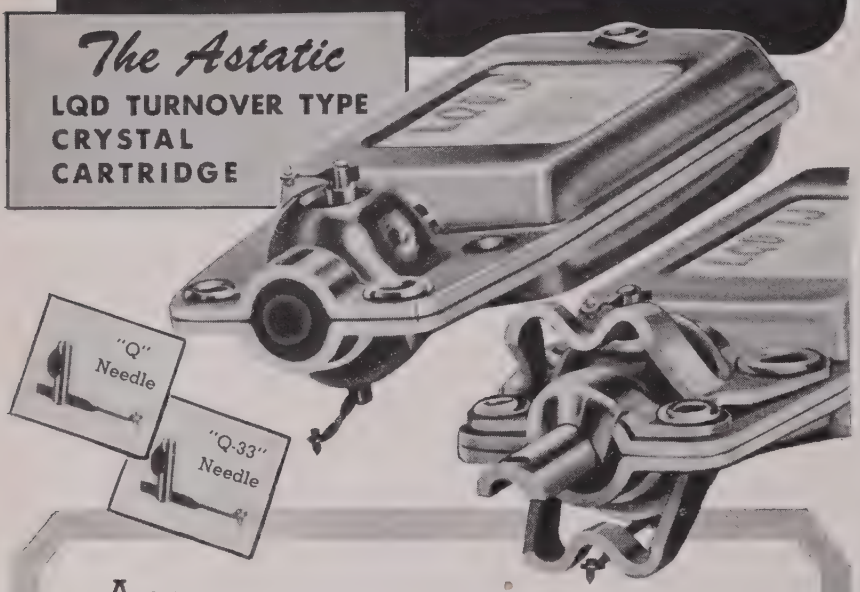
During this stringency, we appeal to the radio industry to restrict its use of our products to applications in which Bradleyunit quality performance is absolutely essential.

ALLEN-BRADLEY COMPANY, 114 W. GREENFIELD AVE., MILWAUKEE 4, WISCONSIN

A DOUBLE-NEEDLE PICKUP CARTRIDGE

with Top Quality Performance Characteristics *plus* the most convenient needle replacement arrangement that has been devised.

The Astatic
LQD TURNOVER TYPE CRYSTAL CARTRIDGE



A GENTLE PRY with penknife or screw driver, and ONE needle comes out of the Astatic LQD Double-Needle Cartridge when replacement is necessary . . . without disturbing the other needle, without removing cartridge from tone arm, without so much as the turn of a screw or use of other tools. Gentle pressure with the tip of a knife blade snaps the new needle into place. This simple arrangement has spearheaded a resounding welcome by large users for Astatic's new LQD Cartridge. Astatic type "Q" Needle, with three mil tip-radius, and "Q-33," with one mil tip-radius, are employed . . . established types which have been on the market for some time and are readily available. The relatively high vertical and lateral compliance of this needle design affords appreciable reduction in needle talk, contributing greatly to the new cartridge's high standard of reproduction.

Listening tests by prospective users have prompted such comments as: "Unquestionably the best we've heard." You are urged to make your own comparisons, note the excellent frequency response particularly at low frequencies, judge for yourself the performance qualities and convenient utility of the Astatic LQD Double-Needle Cartridge. Available with or without needle guards.

SPECIFICATIONS

1. Stamped aluminum housing.
2. Frequency response—50 to 7,000 c.p.s.
3. Output—1.2 volts (Audio-Tone Record, 78 RPM);
   .75 volts (Columbia 281 Record, 33⅓ RPM).
4. Recommended needle pressures—15 grams for 78 RPM and 6 to 8 grams for 33⅓ RPM.

THE Astatic CORPORATION
ASTATIC
CONNEAUT, OHIO
IN CANADA: CANADIAN ASTATIC LTD. TORONTO ONTARIO

Astatic Crystal Devices manufactured under Brush Development Co. patents

The following transfers and admissions were approved and will be affective as of April 1, 1949:

Transfer to Senior Member

Alter, A. R., 1524 68 Ave., Philadelphia 26, Pa.
Boyd, L. K., 1206 Wilson Ave., Santuree, Puerto Rico
Disney, V. H., 2295 Summit, Columbus, Ohio
Fernandez, M., Headquarters Military Air Transport Service, Washington, D. C.
Inglis, A. F., 161 Danbury St., S. W., Washington, D. C.
Jackson, C. H., 31 N. Granada St., Arlington, Va.
Miller, C. E., 1132 Melrose Ave., Glendale 2, Calif.
Overton, B. H., Box 115, Shalimar, Fla.
Schuck, O. H., 4711 DuPont Ave., S., Minneapolis, Minn.
Spencer, B. F., 120 Wilson St., Garden City, L. I., N. Y.
Vogelman, J. H., 676 Westwood Ave., West End, N. J.

Admission to Senior Member

Harder, E. L., 1204 Milton Ave., Pittsburgh 18, Pa.
Kirchenbauer, C. C., 2907 Powhattan Dr., Toledo, Ohio
Liberman, A., 1512 S. Pulaski Rd., Chicago 23, Ill.
Power, D. W., 16 Inwood Rd., Summit, N. J.
Steinberg, E. B., 639 Summer St., Stamford, Conn

Transfer to Member

Auerbach, I. L., 2106 Delancey St., Philadelphia 3 Pa.
Beach, O. R., 1869 W. 38 Pl., Los Angeles 37, Calif.
Bullock, G. M., 21 Danbury St., S. W., Washington 20, D. C.
Clyne, W. E., 521 New Customhouse, Denver 2, Col.
Dakin, O. C., 240 Sutherland Dr., Toronto, Ont., Canada
Fernane, J., Federal Communications Commission, 838 U. S. Court House, Kansas City 6, Mo.
Fleming, J. W., 80 Myrtle Ave., Edgewater, N. J.
Furst, R. E., 520 Cornelia Ave., Chicago 13, Ill.
Gable, N. P., 40-42 Lawrence St., Flushing, L. I., N. Y.
Greenbaum, W. H., 17 Poplar St., Elmsford, N. Y.
Howe, W. E. W., 3940 Second St., Washington 20, D. C.
Hyder, H. R., III, c/o Department 63, Bendix Radio Division, Baltimore 4, Md.
Levin, K. L., 316 Fairfield Ave., Kenmore 17, N. Y.
Mills, C. A., 30 W. Oakland Ave., Oaklyn, N. J.
Muschamp, R. A., 103 Sandra Lane, North Syracuse, N. Y.
Rich, A. P., 1855 Dome Ct., San Pedro, Calif.
Russell, W. W., 146 Poplar Ave., Elmhurst, Ill.
Schwarz, R. J., Dept. of Electrical Engineering, Columbia University, New York 27, N. Y.
Sherbin, L. E., 1112 Gerard Ave., New York, N. Y.
Stephenson, H. B., 102 Byron Ave., Buffalo 17, N. Y.
Trout, C. C., 528 N. Eastern Ave., Indianapolis 1, Ind.
Wilson, L. W., 4015 Front St., San Diego 3, Cal.
Wyman, R. C., 5711 31 Ave., Hyattsville, Md.

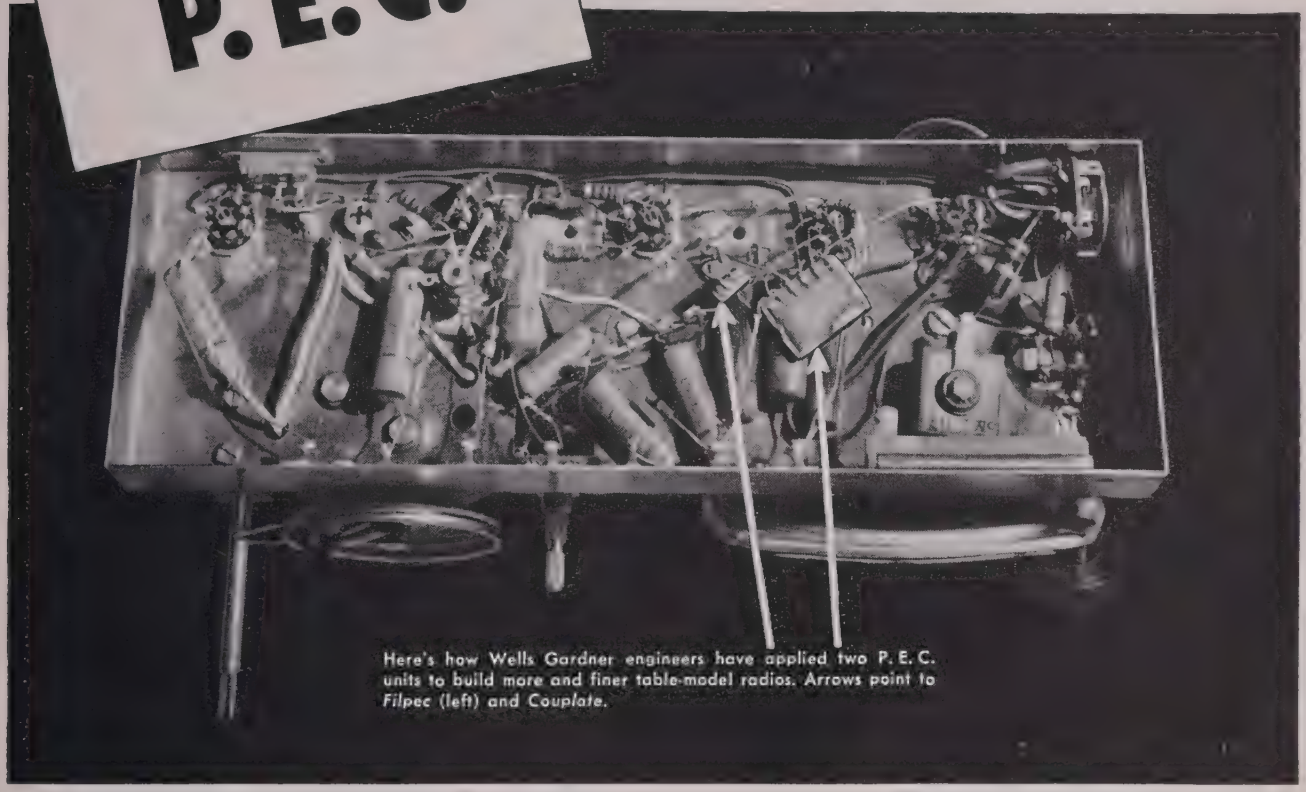
Admission to Member

Ahmed, M. A. H., Electrical Dept., Faculty of Engineering, Cairo, Giza, Egypt
Boutros, O. L., 1629 E. 31 St., Kansas City 3, Mo.

(Continued on page 42A)

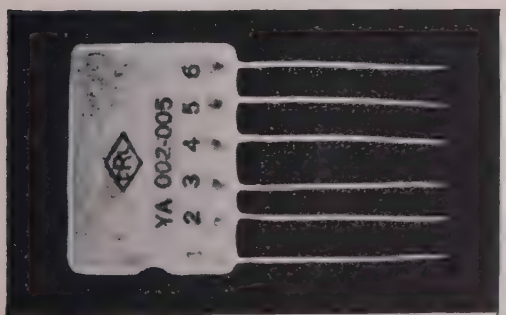
PROGRESS REPORT ON P.E.C.*

How Wells Gardner uses CRL's Pentode *Couplate* and *Filpec* to save space and speed assembly of table-model radios!

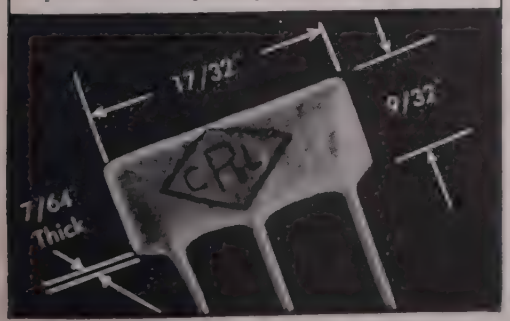


Here's how Wells Gardner engineers have applied two P. E. C. units to build more and finer table-model radios. Arrows point to *Filpec* (left) and *Couplate*.

Chassis courtesy of Wells Gardner & Company



Made with high dielectric Ceramic-X, both *Couplate* (above) and *Filpec* (below) assure long life, low internal inductance, positive resistance to humidity and vibration. All units provided with special phenolic coating.



*Centralab's "Printed Electronic Circuit" — Industry's newest method for improving design and manufacturing efficiency!

MORE and more manufacturers are turning to CRL's space-saving *Printed Electronic Circuits* to help them produce finer products, faster. That's how it is with Wells Gardner & Company, Chicago. Two Centralab P. E. C. units — *Couplate* and *Filpec* — are helping this firm cut assembling time of table-model radios by reducing the number of components needed and by eliminating many soldering operations. What's more, these same units are improving performance of Wells Gardner radios by resisting temperature and humidity . . . by practically eliminating loose or broken connections.

INTEGRAL CERAMIC CONSTRUCTION: Each *Printed Electronic Circuit* is an integral assembly of *Hi-Kap* capacitors and resistors closely bonded to a steatite ceramic plate and mutually connected by means of metallic silver paths "printed" on the base plate.

For complete information about *Filpec* and *Couplate* as well as other CRL *Printed Electronic Circuits*, see your nearest Centralab Representative, or write direct.

LOOK TO **Centralab** IN 1949!

Division of GLOBE-UNION INC., Milwaukee

Broadcast Engineers Helped Design it!
Network Shows Use it!
Now Compare it with any in your Studios!
Nothing like EV High Fidelity Broadcast Dynamics
YOU'VE WANTED microphones like these! Performance meets the highest FM and AM broadcast standards. The bass end is smooth and flat. The highs are particularly clean and peak-free. Construction is extremely rugged and shock-resistant. Omni-directional. Each microphone individually laboratory calibrated and certified. Try one. Compare it with any mike in your own studios.
Write for full facts today!
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ELECTRO-VOICE, INC., BUCHANAN, MICH.
Export: 13 East 40th St., New York 16, U.S.A.
Cables: Arlab
New "650"
Response ±2.5 db, 40 cps to 15 kc.
Output —46db.
External Shock Mount.
Impedance Selector
List Price.....$150
New "645"
Response ±2.5 db, 40 cps to 15 kc.
Output —50 db.
External Shock Mount.
Impedance Selector.
List Price.....$100
The "635"
Response ±2.5 db, 60 cps to 13 kc.
Output —53 db.
Impedance Selector.
For Hand or Stand.
List Price.....$60

MEMBERSHIP

(Continued from page 40A)

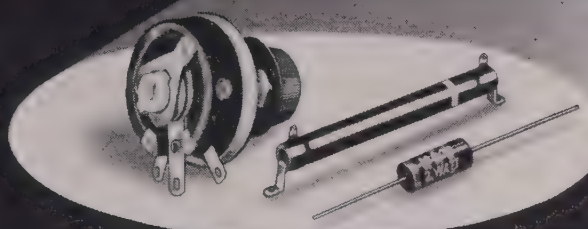
Burch, E. C., 5544 Riggs, Overland Park, Kan.
Daubenheyer, H. W., 6817 Barr Rd., Washington 16, D. C.
Dickinson, R. H., 902 Albany St., Schenectady 7, N. Y.
Dinardo, J. A., 107 W. Sixth St., Emporium, Pa.
Everts, W. J., Chittenango, R. D. 1, N. Y.
Fonda, J. C., 3132 Tyson Ave., Philadelphia 24, Pa.
Hayes, H. J., Jr., Dept. of Electrical Engineering, Engineering Bldg., Princeton University, Princeton, N. J.
Herz, A. J., 22 W. Monroe St., Chicago 3, Ill.
Jefferson, W. E., 302 South St., Halifax, Nova Scotia
Joga Rao, H., No. 8 Murugesa Mudali St., T. Nagar, Madras South India
Kolkedy, J. G., 441 Mellon St., S. E., Washington 20, D. C.
Lavender, R. W., 81 Beethoven St., Binghamton, N. Y.
Mudaliyar, K. N. D., Engg. Supr. Carr., 6 Nataraja Pillai St., Kaveripak, North Arcot, South India
Razdowitz, A., 593 Riverside Dr., New York 31, N. Y.
Rorholt, B. A., E.R.L., Vanserg Bldg., 12 Divinity Pl., Cambridge, Mass.
Rutherford, C. R., Defense Research Laboratory, Box 1, University Station, Austin, Tex.
Skolnik, B. J., 1450 Veteran Ave., West Los Angeles Calif.
Skorup, G. E., 49 Manor Ave., Oaklyn, N. J.
Waters, W. F., 801 Telephone Bldg., Dallas 2, Tex.
Witow, M. I., 130 Cass St., Dayton 2, Ohio

The following admissions to Associate grade were approved and will be effective as of March 1, 1949:

Alcorn, C. L., 25 Arnold Pl., Dayton 7, Ohio
Aycock, E. H., 225 N. Mayo St., Rocky Mount, N. C
Bajaj, P. L., The Vithal Nivas, Block A No. 34, Jacob Circle, Bombay 11, India
Banham, J. C., Gransha Rd., Ballybeen, Dundonald, Belfast, N. Ireland
Barnsdale, E. A., The Risley Club, Risley, Warrington, Lancs., England
Bechtold, H. P., Jr., R.F.D. 365A, John St., Wantagh, N. Y.
Belz, A. R., Herb Lew Rd., Warrington, Pa.
Benda, D., 6804 S. Halsted St., Chicago 21, Ill.
Biagi, A. D., 956 E. 25 St., Paterson 3, N. J.
Blohm, R. W., 4149 N. Bernard St., Chicago 18, Ill.
Bloom, F. J., 10 Hartley Ave., Mount Vernon, N. Y.
Bowman, R. B., KPAN, Hereford, Tex.
Boyd, T. J., Jr., 4213 Oglethrope St., Hyattsville, Md.
Bradley, J. L., 215 N. Bowling Green Way, Los Angeles 24, Calif.
Brody, H., 355 Stockton St., Brooklyn 6, N. Y.
Brogan, J. M., 396 Union St., Jersey City, N. J.
Bruun, D. R., B.O.Q.-B, Naval Ordnance Test Station, China Lake, Calif.
Burger, F. J., 89 Colonial Pkwy., Manhasset, L. I., N. Y.
Carr, R. W., 640 Briar Pl., Chicago 14, Ill.
Castaneda, R. A., 446 W. 38 St., New York 18, N. Y.
Chadney, H. B., 1066 Evergreen Ct., New Milford, N. J.
Chandler, C. F., 29A Caselli Ave., San Francisco 14, Calif.
Chittenden, K. M., 341 Elm St., Oxnard, Calif.

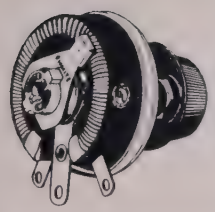
(Continued on page 44A)

Your electronic equipment is no better than its smallest component . . .



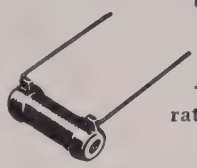
Be Right with OHMITE

CLOSE CONTROL RHEOSTATS



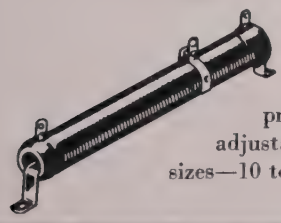
Here is the most extensive line of rheostats offered today . . . 10 sizes, from 25 to 1000 watts, with many resistance values. All-ceramic construction. Windings are locked in vitreous enamel.

VITREOUS ENAMELED RESISTORS



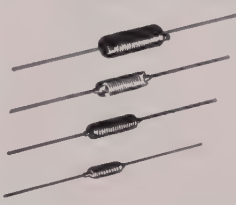
Resistors are wire wound on a ceramic core, rigidly held in place, insulated, and protected by vitreous enamel. Even winding dissipates heat rapidly —prevents hot spots. Many types, in ratings from 5 to 200 watts.

DIVIDOHM ADJUSTABLE RESISTORS



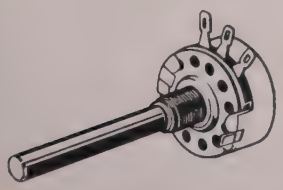
Used as multi-tap resistors or voltage dividers. Narrow strip of exposed winding provides contact surface for the adjustable lug. Available in seven sizes—10 to 200 watts.

RADIO FREQUENCY PLATE CHOKES



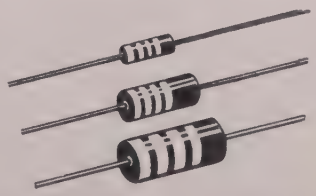
Single-layer wound on low power factor steatite or molded plastic cores. Seven stock sizes cover range 3 to 520 mc. Two units rated 600 ma; all others 1000 ma.

✻MOLDED COMPOSITION POTENTIOMETER



A 2-watt molded composition unit with good margin of safety. It is unaffected by heat, cold, or moisture. Resistance element is a thick, solid-molded ring.

✻MOLDED COMPOSITION RESISTORS



Small and sturdy, these "Little Devil" units come in ½, 1, and 2-watt sizes. 10 Ohms to 22 megohms. Tol. ± 10% and ± 5%.

✻ *So that two exceptionally high-quality products will be universally obtainable, Ohmite Manufacturing Company, in co-operation with the Allen-Bradley Company, has arranged for the Type AB (Allen-Bradley Type J) control and Little Devil Molded Composition Resistors (Allen-Bradley Types EB, GB, and HB) to be available from stock at Ohmite distributors.*

Write for Catalog No. 40

OHMITE MANUFACTURING CO.
4860 Flournoy St., Chicago 44, Ill.

Be Right with OHMITE

RHEOSTATS • RESISTORS • TAP SWITCHES • CHOKES • ATTENUATORS

SHALLCROSS

DECADE RESISTANCE BOXES

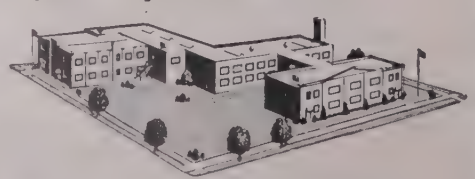
Shallcross Decade Resistance Boxes are sturdily made to high quality standards and with accuracy adjustment of resistors as follows: 0.1 ohm...1%; 1. ohm...0.25% and all others 0.1%.

OVER FORTY TYPES AVAILABLE...
Following are a few of the most popular types normally in stock.

Type	Dials	Steps: Ohms	Total Resistance: Ohms	Dimensions: Inches	Weight: Lbs.
820	3	1	1,110	10 x 6 x 5	3.5
822	3	100	111,000	10 x 6 x 5	3.5
817-A	4	0.01	111.1	10 x 8 x 6	4
819	4	0.1	1,111	10 x 8 x 6	4
825	4	1	11,110	10 x 8 x 6	4
828	4	1,000	11,110,000	10 x 8 x 6	4
817-B	5	0.01	1,111.1	10 x 7 x 6	4
829	5	1	111,110	10 x 7 x 6	4
832	6	1	1,111,110	10 x 7 x 6	4.5
833	6	10	11,111,100	10 x 7 x 6	4.5

SPECIALS . . . to your specifications

As a leading maker of close tolerance resistors and precision instruments, Shallcross is well fitted to design and produce special resistance boxes for practically any application.



SHALLCROSS MFG. COMPANY
Department PR-49, Collingdale, Penna.
ENGINEERING • DESIGNING • MANUFACTURING

(Continued from page 42A)

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Daniel, R. D., 400 Pennsylvania Ave., San Francisco 10, Calif.
Deans, W. L., 24 Linden St., Malverne, L. I., N. Y.
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Doane, E. A., 1156 Constance St., Pasadena 6, Calif.
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Eisenmeyer, J. S. 4417 13 Ave., Brooklyn 19, N. Y.
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Ferreira, E., 2749 Chelsea Dr., Oakland 11, Calif.
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Fortune, R. L., 209 E. Main St., Trotwood, Ohio
Friedrich, V. L., 237 Brighton Ave., West End, N. J.
Ftacek, J. J., 1900 Ottawa, Ottawa, Ill.
Garber, M. L., Radio Station KCOW, Alliance, Neb.
Gerdemann, E. A., 226 N. Robert Blvd., Dayton 2, Ohio
Gismot, W., 2401 ½ Palm Pl., Huntington Park, Calif.
Goldstein, M., 3602 Ave. J, Brooklyn, N. Y.
Hadlock, C. F., 41 Bellington St., Arlington, Mass.
Hale, H. E., Hq. and Hq. Sqdn., AAC, c/o Postmaster, Box 29, Seattle, Wash.
Hamann, K. R., O & R Electronics Department, U. S. Naval Air Station, San Diego 25, Calif.
Hardwick, C. L., 2905 Chestnut St., Fort Wayne 4, Ind.
Haywood, B. M., 228 Newport News Ave., Hampton, Va.
Hein, Edith, 178 Ocean Pkwy., Brooklyn 18, N. Y.
Honaski, H. J., 68 Davis St., Locust Valley, L. I., N. Y.
Hubbard, N. S., Nairobi, Kenya Colony, East Africa
Inokuchi, T., 4351 Oakenwald Ave., Chicago 15, Ill.
Isenberg, R. H., Box 276, China Lake, Calif.
Jennings, F. S., 2100 Fisher Bldg., Detroit 2, Mich.
Karlberg, B. G., 1324 Balltown Rd., Schenectady, N.Y.
Keefe, J., Jr., 325 Cooper St., Camden, N. J.
Keller, E. A., 9 Probusweg, Zurich 57, Switzerland
Kellerman, D., 170 Ludlow St., New York 2, N. Y.
Kent, O. J., 841 N. 26 St., Milwaukee 3, Wis.
Kimbell, G. D., 83 Crocker St., San Francisco 3, Calif.
Kjaer, V., A/S Bruel & Kjaer, Naerum, Denmark
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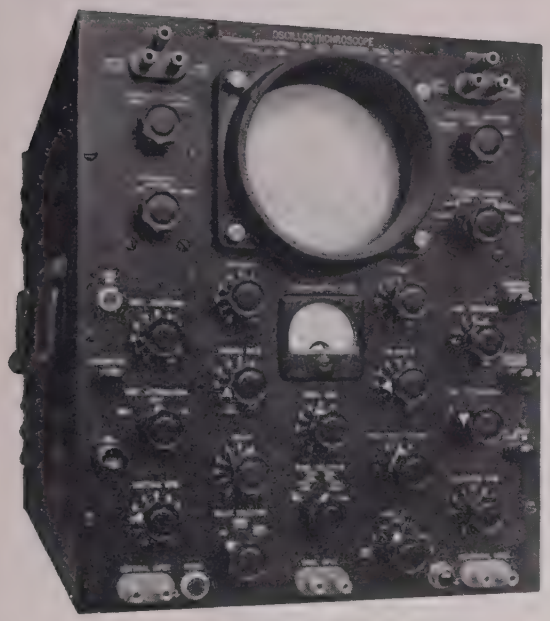
LaPenna, F. W., 167 Chestnut Ave., Staten Island, N. Y.
Lawser, H. W., 548 Belleforte Ave., Oak Park, Ill.
Leite, R. C., 812 Clinton St., Fremont, Ohio
Liberatore, D. F., 105 Elmwood Ct., Emporium, Pa.
Lincoff, W., 199 E. Third St., New York 9, N. Y.
Long, F. R., 52 Warner Ave., Jersey City 5, N. J.
Martin, C. B., 508 S. Johnson Ave., Urbana, Ill.
Martin, E. L., 1119 23 St., S. E., Cedar Rapids, Iowa
McDonald, L. J., Bendix Products Division, Bendix Aviation Corp., South Bend, Ind.
McFee, J. L., 722 N. Broadway, Milwaukee, Wis.
Miller, J. W., Box 374, State College, Pa.
Mims, A. J., 3348 Sanders St., Houston 4, Tex.
Morris, M. J., 136 Park Ave., Yonkers, N. Y.
Morris, R. B., 168 Conway Rd., Decatur, Ga.
Moscovice, M., 96-18 63 St., Queens, L. I., N. Y.
Myklebust, R. J., Box 844, Salt Lake City, Utah
Myse, A. G., Jr., 1338 W. Cullerton St., Chicago 8, Ill.

(Continued on page 46A)

Browning OSCILLOSYNCHROSCOPE MODEL OL-15B



Combining the functions of

OSCILLOSCOPE and SYNCROSCOPE

An Outstandingly Versatile Instrument

Applicable to—

- **TELEVISION**
- **FACSIMILE**
- **PULSE MODULATION**
- **RADAR**
- **NUCLEAR PHYSICS**
- **COMMUNICATIONS**

GENERAL FEATURES

Five-inch cathode ray tube operating at 4,000 volts accelerating potential. Ordinarily supplied with P1 phosphor, others available on special order.

Vertical amplifier flat within 3 db. from 5 cycles to 6 megacycles. One inch deflection with .05-volt RMS input.

Horizontal amplifier flat within 1 db. from 5 cycles to 1 megacycle.

Built-in calibrating system for determining wave amplitude. No external meter needed.

Deflection plates and intensity grid available directly at front panel terminals.

No waiting for trace to reappear after adjusting gain or applying DC component to input.

Low capacitance, high impedance probe supplied for minimizing test circuit disturbance.

Reasonably symmetrical waves permit full screen vertical deflection.

Contained in single cabinet, weighs less than 100 pounds.

AS AN OSCILLOSCOPE

Linear sawtooth sweeps continuously variable from 5 to 500,000 per second in conjunction with the excellent vertical amplifier outlined. Permits observation of RF waves and envelopes to above 6 megacycles. Because of the extended ranges of the amplifiers and sweep generator, oscilloscopic capabilities are correspondingly increased over standard oscilloscopes.

AS A SYNCHROSCOPE

An internal trigger generator continuously variable from 200 to 5,000 cycles can be used to excite external equipment as well as the sweeps. The trigger can be made by panel control to lead or lag the start of the sweep by amounts up to 1,000 microseconds, making it possible to phase any part of a pulse or transient onto the screen for measurement. Sweep speeds of $\frac{1}{4}$, $\frac{1}{2}$, 1, 5, 20, and 200 microseconds per inch provide convenient image time expansion for detailed observation. As the sweep generator will sweep once for each incoming pulse, single transients or pulses occurring at irregular intervals can be observed or photographed.

For more detailed information write for descriptive Bulletin RO-449

• COMPANION INSTRUMENTS •

SWEEP CALIBRATOR MODEL GL-22

For accurately calibrating sweeps. Markers are provided at 1/10, $\frac{1}{2}$, 1, 10, and 100 microsecond intervals which may be applied as deflection or as intensity modulation. May be triggered directly from OL-15B. Write for bulletin RC-449.

FAIRCHILD OSCILLO-RECORD CAMERA

For permanent records of waveforms on 35 mm. film. Single frames or variable continuous motion permit recording of all phenomena. Various lenses, magazines, etc. available. Easily set up with OL-15B. Write for bulletin RF-449.

Canadian Representative
MEASUREMENTS ENGINEERING
Arnprior, Ontario

BROWNING
Laboratories, Inc.
Winchester, Mass.
ENGINEERED FOR ENGINEERS

NEW...

MECHANICAL CONSTRUCTION

FOR

DAVEN DECADES

Special Features

- SWITCH: Patented knee-action switch for high contact pressure and low, uniform, contact resistance.
- VIBRATION PROOF-CONSTRUCTION: Will withstand the Signal Corps Vibration tests.
- CONTACT RESISTANCE: .002 ohm. Will remain within .0003 ohm throughout the life of the unit.
- TYPE OF WINDING
  1, 10, 100 ohm steps—Ayrton-Perry wound.
  0.1 ohm steps—bifilar wound.
  1,000 and 10,000 ohm steps—unifilar wound.
- TYPE OF WIRE: All units up to 10,000 ohms are wound with manganin. Values over 10,000 ohms are wound with nichrome alloy.
- TEMPERATURE COEFFICIENT: All resistors have a temperature coefficient of less than ± .002% per degree C, at room temperature.
- FREQUENCY CHARACTERISTICS:
  0.1, 1, 10, and 100 ohm steps—flat to 1 MC.
  1,000 ohm steps—flat to 50 KC.
  10,000 and 100,000 ohm steps—flat over the audio range.

This new construction is supplied on individual decade units and in decade resistance boxes.

For further information write to Dept. IE-8

(Continued from page 44A)

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Noveske, T. J., Y.M.C.A., Rm. 513, Cleveland, Ohio
Orr, W., 4358 Westerville Re., Columbus 11, Ohio
Palfreman, E. G., P. & T. Department, Khartoum, Sudan, Africa
Pancholy, N. H., Saraswati Society, P. O. Anandnagar, Ahmedabad 7, India
Papamarcos, G., 526 Bay Ridge Ave., Brooklyn 20, N. Y.
Perry, G. C., Box 459, Clinton, Ont., Canada
Pochop, L. C., Box 579, U. S. Naval Ordnance Test Station, China Lake, Calif.
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Przybyla, E. M., 110–19 196 St., St. Albans, L. I., N. Y.
Quinn, W. H., 3 Alexander Ave., Freehold, N. J.
Raha, H. N., 1B Priyanath Banerji St., Calcutta, India
Rajagopalachary, V. V., Radio & Electric Engineering Syndicate, Masulipatam, Kistna, South Africa
Raub, R. D., 100 Kingsland Rd., Clifton, N. J.
Reiss, E. V., 2436 Yates Ave., New York 67, N. Y.
Richardson, J. E., B.O.Q., Naval Ordnance Test Station, China Lake, Calif.
Ridenour, H. E., 615 S. Darling St., Angola, Ind.
Riley, C. D., 200 Clinton St., Brooklyn 2, N. Y.
Salvano, D. P., 1314 Fourth Ave., Asbury Park, N. J.
Sampath, S., c/o P. Srinivasa Iyengar, Advocate, Main Rd., Cuddalore N. T., S. I. Ry., India
Schaffer, L. I., College Village 34-A, Winston-Salem, N. C.
Schiff, A., 1768 Weeks Ave., New York 57, N. Y.
Sciez, L. C., 802 W Flesheim St., Iron Mountain, Mich.
Segal, R. E., 2277 Andrews Ave., New York 53, N. Y.
Shuskus, J. M., 3625 Minnesota Ave., S. E., Washington, D. C.
Sinha, R. B. P., Kosi H. D. I. Division, P. O. Jogbani, Dist. Purnea, India
Sommers, C. E., Freed Radio Corp., 200 Hudson St., New York 13, N. Y.
Stearns, C. F., 1922 W. Adams, Chicago 12, Ill.
Sullivan, A. W., Apt. 48-N, Flavet 1, Gainesville, Fla.
Swift, I. H., 602B Essex Circle, China Lake, Calif.
Teegarden, J. W., 2813 Kenmore Ave., Dayton 10, Ohio
Tiger, H. S., 271 W. 90 St., New York 24, N. Y.
Tracy, R. C., 1515 W. Monroe, Chicago 7, Ill.
Trelewicz, E. R., 7931 71 Ave., Glendale 27, L. I., N. Y.
Trent, I., 1326 Fulton Ave., New York, N. Y.
Uminowicz, A. J., 213 Van Nostrand Ave., Jersey City, N. J.
Urbanik, J. G., 108 Rockville Centre Pkwy., Oceanside, L. I., N. Y.
Vale, S. D., 1634 N. Parkside, Chicago 47, Ill.
Vandervoort, A., 54 Morningside Dr., New York 25, N. Y.
VanderWerf, J. L., 11442 S. Yale Ave., Chicago 28, Ill.
Veltfort, T. E., Jr., 827 Middlefield Rd., Palo Alto, Calif.
Ward, R. H., 25 Mansion St., Poughkeepsie, N. Y.
Weiner, L. H., 201 Boerum St., Brooklyn 6, N. Y.
Weingaertner, W. S., 168–33 119 Ave., Jamaica, L. I., N. Y.
Whitehorn, R. M., 210 Northfield Pl., Baltimore 10, Md.

(Continued on page 48A)

MICROWAVE PLUMBING

10 CENTIMETER

WAVEGUIDE DIRECTIONAL COUPLER, 27 db. Navy type CABV-47AAN, with 4 in. slotted section as shown $42.50
SQ. FLANGE to rd choke adapter, 18 in. long OA 1½ in. x 3 in. guide, type "N" output and sampling probe $32.00
"S" BAND CRYSTAL MOUNT, gold plated, with 2 type "N" connectors $12.50
POWER SPLITTER: 726 Klystron input, dual "N" output $5.00
MAGNETRON TO WAVEGUIDE coupler with 721-A duplexer cavity, gold plated $27.50
10 CM WAVEGUIDE SWITCHING UNIT, switches 1 input to any of 3 outputs. Standard 1½" x 3" guide with square flanges. Complete with 115 vac or dc arranged switching motor. Mfg. Raytheon. CRP 24AAS. New and complete $150.00
10 CM END-FIRE ARRAY POLYRODS ....$1.75 ea.
"S" BAND Mixer Assembly, with crystal mount, pick up loop, tunable output $3.00
721-A TR CAVITY WITH TUBE. Complete with tuning plungers $12.50
10 CM. McNALLY CAVITY Type SG $3.50
WAVEGUIDE SECTION, MC 445A, rt. angle bend, 5¾" ft. OA. 2" slotted section $21.00
10 CM OSC. PICKUP LOOP, with male Homedell output $2.00
10 CM DIPOLE WITH REFLECTOR in lucite ball, with type "N" or Sperry fitting $4.50
10 CM FEEDBACK DIPOLE ANTENNA, in lucite ball, for use with parabola $8.00

⅞" RIGID COAX—⅜" I.C.

RIGHT ANGLE BEND, with flexible coax output pick-up loop $8.00
SHORT RIGHT ANGLE bend, with pressurizing nipple $3.00
RIGID COAX to flex coax connector $3.50
STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $5.00
RT. ANGLES for above $2.50
RT. ANGLE BEND 15" L. OA $3.50
FLEXIBLE SECTION, 15" L. Male to female **$4.25**
MAGNETRON COUPLING to ⅞" rigid coax, with TR pickup loop, gold plated $7.50

⅞" RIGID COAX—¼" I.C.

⅞" RIGID COAX. Bead Supported .....$1.20 per ft.
SHORT RIGHT ANGLE BEND $2.50
Rotating joint, with deck mounting $15.00
RIGID COAX slotted section CU-60/AP $5.00

1.25 CENTIMETER

"K" BAND FEEDBACK TO PARABOLA HORN, with pressurized window $30.00
MITRED ELBOW cover to cover $4.00
TR/ATR SECTION choke to cover $4.00
FLEXIBLE SECTION 1" choke to choke $5.00
ADAPTER, rd. cover to sq. cover $5.00
MITRED ELBOW and S sections choke to cover..$4.50
PICKUP Loop, Type "N" output 10 cm $2.75
TR Box Pick Up Loop 10 cm. $1.25

****

MICROWAVE TEST EQUIPMENT

W. E. I 138. Signal generator, 2700 to 2900 Mc range. Lighthouse tube oscillator with attenuator & output meter. 115 VAC input, reg. Pwr. supply. With circuit diagram $50.00
3 cm. Wavemeter: 9200 to 11,000 mc transmission type with square flanges $15.00
3 cm. stabilizer cavity, transmission type $20.00
3 cm. Wavemeter, Micrometer head mounted on X-Band guide. Freq. range approx. 7900 to 10,000 Mc. $75.00
THERMISTOR BRIDGE: Power meter I-203-A. 10 cm. mfg. W.E. Complete with meter, interpolation chart, portable carrying case as shown $72.50
TS 12/AP VSWR METER, Consisting of Slotted Line, and all additional fittings and ampl. for 3CM operation. New and complete $450.00
Bell Labs. Dual Mount mixer-beacon assemblies, 2 complete mixer-beacon mounts on gold-plated waveguide section $50.00
Slotted Line, Bell Labs. 1¼" x 5/16" guide, gold plated $150.00

****

MICROWAVE GENERATORS

AN/APS-15A "X" Band compl. RF head and modulator, incl. 725-A magnetron and magnet, two 723A/B klystrons (local osc. & beacon), 1B24 TR, rcvr-ampl, duplexer, HV supply, blower, pulse xtmr. Peak Pwr. Out: 45 KW apx. Input: 115, 400 cy. Modulator pulse duration .5 to 2 micro-sec. apx. 13 KV Pk Pulse. Compl. with all tubes incl. 715-B, 829B, RKR 73, two 72's. Compl. pkg., new $210.00
APS-15B. Complete pkg. as above, less modulator $150.00
"S" BAND AN/APS-2. Complete RF head and modulator, including magnetron and magnet, 417-A mixer, TR, receiver, duplexer, blower, etc., and complete pulser. With tubes, used, fair condition $75.00
10 CM RF Package. Consists of: SO Xmtr-receiver using 2127 magnetron oscillator, 250 KW peak input. 707-B receiver-mixer $150.00
Modulator-motor-alternator unit for above....$ 75.00
Receiver-rectifier power unit for above.....$ 25.00
Rotating Ant. with parabolic reflector for above. New .....$ 75.00

POWER EQUIPMENT

STEP DOWN TRANSFORMER: Pri: 440/220/110 volts a.c. 60 cycles. 3 KVA. Sec. 115 v. 2500 volt Ins. 12" x 12" x 7" $40.00
PLATE Transformer; Pri: 117 v. 60 cy Sec. 17,000 v @ 144 ma. w/ choke. Oil filled. Size 26" x 29" x 13" AMERTRAN ...$120.00

"Communications"

SEE CEC FOR YOUR NEEDS

MAGNETRONS

TUBE	FREQ. RANGE	PK. PWR. OUT.	PRICE
2J31	2820-2860 mc.	265 KW.	$25.00
2J21-A	9345-9405 mc.	50 KW.	$25.00
2J22	3267-3333 mc.	265 KW.	$25.00
2J26	2992-3019 mc.	275 KW.	$25.00
2J27	2865-2992 mc.	275 KW.	$25.00
2J32	2780-2820 mc.	285 KW.	$25.00
2J37			$45.00
2J38 Pkg.	3249-3263 mc.	5 KW.	$35.00
2J39 Pkg.	3267-3333 mc.	87 KW.	$35.00
2J40	9305-9325 mc.	10 KW.	$65.00
2J49	9000-9160 mc.	58 KW.	$85.00
2J55 Pkg.	9345-9405 mc.	50 KW.	$35.00
2J61	3000-3100 mc.	35 KW.	$65.00
2J62	2914-3010 mc.	35 KW.	$65.00
3J31	24,000 mc.	50 KW.	$55.00
5J30			$39.50
714AY			$25.00
718DY			$25.00
720BY	2800 mc.	1000 KW.	$50.00
720CY			$50.00
725-A	9345-9405 mc.	50 KW.	$25.00
730-A	9345-9405 mc.	50 KW.	$25.00

Klystrons: 723A/B $12.50; 707B W/Cavity $20.00
417A $25.00 2K41 $65.00

MAGNETRON MAGNETS

GAUSS	POLE DIAM.	SPACING	PRICE
4850	¾ in.	⅝ in.	$12.50
2500	1⅝ in.	1 11/16 in.	$12.50
1500	1⅝ in.	1½ in.	$12.50
D161392*	1⅝ in.	1 5/16 in.	$12.50

* Mfr's Number.

TUNABLE PKGD. "CW" MAGNETRONS

QK 61 2975-3200 mc. **QK 62** 3150-3375 mc.
QK 60 2800-3025 mc. **QK 59** 2675-2900 mc.
New, Guaranteed .....Each $65.00

3 CENTIMETER PLUMBING

(STD. 1" x ½" GUIDE, UNLESS SPECIFIED)

"X" BAND PREAMPLIFIER, consisting of 2-723 A B local oscillator-beacon feeding waveguide and TR/ATR Duplexer sect, incl. 60 mc IF amp $47.50
Random Lengths wavegd, 6" to 18" Lg. ...$1.10 Ft.
WAVEGUIDE RUN 1⅛" x 1/2" guide, consisting of 4 ft. section with Rt. angle bend on one end 2" 45 deg. bend other end $8.00
WAVEGUIDE SECTION 1⅛" x ½" choke to choke 4 ft. long. $10.00
Dummy Load. Ts 332/UP $22.50
"X" BAND PRESSURIZING gauge section w/15-lbs gauge Section w/15-lbs gauge & Pressurizing Nipple $18.50
45 DEG. TWIST 6" Long $10.00
12 SECTION 45 deg twist 90 deg. bend $6.00
11 STRAIGHT WAVEGUIDE section choke to cover
15 DEG BEND 10" choke to cover $4.50
special heavy construction Silver plated $4.50
5 FT SECTIONS choke to cover $14.50
18" FLEXIBLE SECTION $17.50
"E" and "H" PLANE BENDS $12.50
BULKHEAD FEED THRU $15.00
"X" BAND WAVEGUIDE 1¼" x ⅝" OD 1/16" wall Aluminum .....Per Foot $ .75
WAVEGUIDE 1" x ½" I.D. .....Per Foot $1.50
TR CAVITY For 724-A TR Tube $3.50
3" FLEX SECT. sq. flange to Circ Flang Adapt. $7.50
724 TR TUBE (41-TR-1) $2.50
TR/ATR DUPLEXER Sect. w/iris flange $8.00
Twist 90 deg. 5" choke to Cover w/press nipple $6.50
Waveguide Sections 2½ ft. long silver plated with choke flange $5.75
WAVEGUIDE 90 deg. bend "E" Plane, 18" Lg $4.00
Rotary Joint choke to choke $17.50
Rotary Joint, choke to choke with deck mounting $17.50
S. CURVE WAVEGUIDE 8" Lg. cover to choke $3.50
DUPLEXER SECTIONS FOR 1B24 .....$10.00
CIRCULAR CHOKE FLANGES solid brass .....$.55
SQ. FLANGES FLAT BRASS .....ea. $.55
APS-10 TR/ATR DUPLEXER section with additional IRIS Flange $10.00
CU 105/APS 31 Directional coupler 25 lb. $15.00
CU 103/APS 33 Directional coupler 25 lb. $15.00
FLEXIBLE WAVEGUIDE .....$4.00/FT.
"X" BAND calibrated attenuator $85.00
SHIELDED KLYSTRON Tube Mounts with rough attenuator outputs $90.00
FLEXIBLE SECTION 2½" cover to cover $5.00
TRANSITION WAVEGUIDE ⅝" x ⅝" x 1" x ½" x 14" L. .....ea. $8.00

THERMISTORS		VARISTORS	
D-167332 (tube)	$.95	D-171631	$.95
D-170396 (bead)	$.95	D-167176	$.95
D-167613 (button)	$.95	D-168687	$.95
D-166228 (button)	$.95	D-171812	$.95
D-164699 for MTG. in "X" band Guide	$2.50	D-171528	$.95
D-167018 (tube)	$.95	D-168549	$.95
		D-162482	$3.00
COAX PLUGS		D-166277	$2.50
831SP	$.35	D-162356	$1.50
831AP	$.35	D-161874	$2.85
831HP	$.15	D-163075	$1.25
UG 21/U	$.85	3A(12-43)	$1.50
UG 86 U	$.95	D167020	$3.00
UG 254/U	$.75		

PULSE EQUIPMENT

MODULATOR UNIT BC 1203-B

Provides 200-4,000 PPS. Sweeptime: 100 to 2,500 microsec. in 4 steps, fixed mod. pulse, suppression pulse, sliding modulating pulse, blanking voltage, marker pulse sweep voltages, calibration voltages, fil. voltages. Operates 115 vac. 50-60 cy. Provides various types of voltage pulse outputs for the modulation of a signal generator such as General Radio ‡804B or ‡804C used in depot bench testing of SCR 695, SCR 595, and SCR 535. New as shown $125.00
MIT. MOD. 3 HARD TUBE PULSER: Output Pulse Power: 144 KW (12 KV at 12 amp). Duty Ratio: .001 max. Pulse duration: 5, 1.0, 2.0 microsec. Input voltage: 115 v. 400 to 2400 cps. Uses 1-715-B, 1-829-B, 3-72's, 1-73. New $110.00
APQ-13 PULSE MODULATOR. Pulse Width .5 to 1.1 Micro Sec. Rep. rate 624 to 1348 Pps. Pk. pwr. out 35 KW. Energy 0.018 Joules $49.00
TPS-3 PULSE MODULATOR. Pk. power 50 amp. 24 KV (1200 KW pk); pulse rate 200 PPS, 1.5 microsec; pulse line impedance 50 ohms. Circuit—series charging version of DC Resonance type. Uses two 705-A's as rectifiers, 115 v. 400 cycle input. New with all tubes $49.50
APS-10 MODULATOR DECK. Complete, less tubes $75.00
APS-10 Low voltage power supply, less tubes ..$18.50

PULSE NETWORKS

G.E. ‡25E5-1-350-50P2T, 25 KV, 5 sections, "E" circuit, 1 microsecond pulse length, 350 PPS, 50 ohms impedance $45.00
G.E. ‡6E3-5-2000-50P2T, 6KV, "E" circuit, 3 sections, .5 microsecond, 2000 PPS, 50 ohms impedance .$6.50
G.E. ‡3E (3-.84-810; 8-2.24-405) 50P4T: 3KV, "E" CKT Dual Unit: Unit 1, 3 Sections, .84 Microsec, 810 PPS, 50 ohms imp.; Unit 2, 8 Sections, 2.24 Microsec, 405 PPS, 50 ohms imp. $6.50
7.5E3-1-200-67P, 7.5 KV, "E" Circuit, 1 microsec, 200 PPS, 67 ohms impedance, 3 sections $7.50
7.5E4-16-60-67P, 7.5 KV, "E" circuit, 4 sections, 16 microsec, 60 PPS, 67 ohms impedance $15.00
7.5E3-3-200-6PT, 7.5 KV, "E" Circuit, 3 microsec, 200 PPS, 67 ohms imp., 3 sections $12.50

DELAY LINES

D-168184: .5 microsec, up to 2000 PPS, 1800 ohm term $4.00
D-170499: .25/.50/.75/. microsec. 8 KV. 50 ohms imp. $16.50
D-165997: 1¼ microsec. $7.50

PULSE TRANSFORMERS

G.E.K.-2745 .....$39.50
G.E.K.-2744-A $39.50
W.E. $D166173 HI-Volt input transformer, W.E. Impedance ratio 50 ohms to 900 ohms. Freq. range: 10 kc to 2 mc, 2 sections parallel connected, potted in oil $36.00
W.E. KS 9800 Input transformer. Winding ratio between terminals 3-5 and 1-2 is 1.1:1, and between terminals 6-7 and 1-2 is 2:1. Frequency range: 380-520 c.p.s. Permalloy core $6.00
G.E. ‡K2731 Repetition Rate: 635 PPS, Pri. Imp: 50 Ohms, Sec. Imp: 450 Ohms. Pulse Width: 1 Microsec. Pri. Input: 9.5 KV PK, Sec. Output: 28 KV PK. Peak Output: 800 KW. Bifilar 2.75 Amp. $64.50
W.E. $D169271 Hi Volt input pulse Transformer $27.50
G.E. K2450A Will receive 13KV, 4 micro-second pulse on pri., secondary delivers 14KV. Peak power out 100KW GE $45.00
G.E. ‡K2748A Pulse Input, line to magnetron ..$36.00
‡9280 Utah Pulse or Blocking Oscillator XFMR. Freq. limits 790-810 cy-3 windings turns ratio 1:1:1 Dimensions 1 13/16 x 1 1/8 x 19/32" $1.50

400 CYCLE TRANSFORMERS

352-7273: Pri; 115V, 400 cy. Sec: 6.3V, 2.5 Amp; 6.3V, .06 Amp; 6.3V, .9 Amp; 5V, 6 Amp; 700 VCT. 2-5U4's. For **APS-15.** T201 .....$4.75
352-7176: Pri: 115V, 400 cy. Sec: 6.3V, 20 Amp; 6.3V, .5 Amp; 6.3V, .5 Amp; 320V (2-6x5's). For **APS-15.** T202 .....$5.25
352-7278: Pri: 115V, 400 cy. Sec: 2.5V, 1.75 Amp, 3500V (2x2). For **APS-15.** T203 (Anode ‡2 5FP7) $5.85
352-7070: Pri: 115V, 440 cy. Sec. 2.5V, 2.5 Amp: 2.5V 2.5 Amp: (2000V. Ins.); 6.3V, 2.25 Amp: 1200V. Tpd. at 1000 and 750V, P/o **AN/APS 15** $4.95
‡7469105: Pri: 115V, 400 cy. Sec: Tpd. to give 742.5V, 50 MA; 709V, .0477 A. 671V, .045 A. $2.95
M-7474319: Pri: 115V, 400 cy. Sec: 6.3V, 2.7 Amp; 6.3V, 66 Amp; 6.3V, .21 Amp. $2.95
32332: Pri: 115V, 400-2400 cy. Sec: 400 Vct, 35 MA: 6.4V, 2.5 Amp; 6.4V, .15 Amp. $2.25
332-7138M: Pri: 115V, 400-2400 cy. Sec: 640V, .5 MA: 2.5V. 1.75 Amp. $3.85
352-7179: Pri: 115V, 400-2400 cy. Sec: 6.5V, 12 Amp, Ct. 250V, 100 MA; 5V, 2 Amp. $3.50
‡9069: Pri: 115/80V, 400-2600 cy. Sec: 650 Vct. 50 MA; 6.3 Vct, 2 Amp; 5 Vct, 2 Amp. $2.15
352-7096: Pri: 115/80V, 400-2400 cy. Sec: 2.5V, 1.75 Amp, 3 Kv. Ins.; 5V, 3 Amp; 6.5V, 6.5 Amp; 6.5V, 1.2 Amp. $3.95
KS 9607: Pri: 115V, 400-2400 cy. Sec: 734 Vct. 177 MA. 1710 Vct, 177 MA. $5.95
D-166333: Pri: 115V, 400-2400 cy. Sec: 6.3V, 0.8 Amp, 7.7V, 0.365 Amp. $2.79
GE ‡7471957: Pri: 100/110/120/130V, 400-2400 cy. Sec: 2.5V, 20 Amp. HV ins. $4.85
D-163254: Pri: 115V, 400 cy. Sec: 6.3V, 12 Amp; 6.3V, 2A; 6.3V, 1A. **P/O AN/APQ5** $5.85
KS-9685: Pri: 115V, 400-2400 cy. Sec: 6.4Vct, 7.5 Amp; 6.4V, 3.8 Amp; 6.4V, 2.5 Amp. $4.35
using 2127 magnetron oscillator, 250 KW peak input. 707-B receiver-mixer $150.00
Modulator-motor-alternator unit for above ....$ 75.00
Receiver-rectifier power unit for above .....$ 25.00
PLATE XFMR: Pri: 115V, 400 cy. Sec: 9800V. or 8800V. @ 32 MA. DC. $12.50

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(Continued from page 46A)

Wilkinson, R. L., 408 York Rd., Baltimore, Md.
Williams, R. W., 3097 Walnut St., Huntington Park, Calif.
Yondorf, E. G., 615 Cator Ave., Baltimore 18, Md.
Zion, H., 162–23 73 St., Flushing, L. I., N. Y.

The following transfers to Associate grade were approved to be effective as of January 1, 1949:

Anthony, J. P., 3546 Ozark, Houston 4, Tex.
Arnold J. B., 209–27 Hillside Ave., Apt. S, Queens Village, L. I., N. Y.
Barnes, P. M., Sandia Base Branch, Albuquerque, N. Mex.
Battaglino, V., Puan 383, Buenos Aires, Argentina
Belfi, J. L., 83 MacDougal St., New York 12, N. Y.
Boulet, L., Department of Engineering, Laval University, Quebec, Que., Canada
Burke, M. H., R.F.D. 1, Box 25, Farmingdale, N. J.
Carlson, C. G., 11206 91 St., Edmonton, Alta., Canada
Darr, J. E., 402 Ross Ave., Wilkinsburg 21, Pa.
Dobler, J. W. H., Jacob Ford Village, Bldg. 10, Apt. 1A, Morristown, N. J.
Doel, D., 358 Kellogg Park, Portland 2, Ore.
Falk, A. K., 1330 Carleton St., Port Huron, Mich.
Freyman, R. W., 418 Kiva St., Los Alamos, N. Mex.
Giordano, A. F., 112 Third Ave., Newark 4, N. J.
Gough, L. E., Box 548, State College, N. Mex.
Groves, Q. D., 26 Wellington Rd., Merrick, L. I., N. Y.
Hiatt, W. C., R.F.D. 2, Hope, Ind.
Howie, J. S., 38 Nelson St., Gordon, N. S. W., Australia
Kaplan, H., 5553 W. Congress St., Chicago 44, Ill.
Krainin, S., 222–07 141 Ave., Laurelton 13, N. Y.
Lashier, H. M., Emmanuel Missionary College, Berrien Springs, Mich.
Lepanto, P. J., 35–28 95 St. Jackson Heights, L. I., N. Y.
Lewis, M. B., 3051 Ocean Ave., Brooklyn 29, N. Y.
Malone, W. C., Jr., 8071 Mountain Blvd., Oakland 5, Calif.
Mattison, G. H., 3215 Corlear Ave., New York 63, N. Y.
Montgomery, R. A., Rm. 239, Bldg. 37, General Electric Co., Schenectady, N. Y.
Moore, R. E., 17 Glen Ave., Scotia, N. Y.
Nevitt, R. G., 613 So. Western Pkwy., Louisville 11, Ky.
Nichols, F. K., Department of Electricity, U. S. Military Academy, West Point, N. Y.
Paul, W., 1458 University Ter., Ann Arbor, Mich.
Peckhart, M. A., R.F.D. 1, Fort Wayne, Ind.
Pimenoff, V. J., Department of Physics, University of New Brunswick, Fredericton, N. B., Canada
Powell, M., Jr., 896 Idlewild Dr., Madison, Tenn.
Preziosi, F. W., 7466 St. Denis St., Montreal, Que., Canada
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Rubin, W. L., 3549-12 Ave., Brooklyn 18, N. Y.
Salsbury, D., 44 Harvest Lane, Hicksville, L. I., N. Y.
Schupp, G. A., Jr., 40 Cedar St., Worcester, Mass.
Seidler, R. L., 179 N. Main St., Spring Valley, N. Y.
Simon, A., 354 Bergen Ave., Jersey City, N. J.
Sperrazzo, V. J., 161 Troutman St., Brooklyn, N. Y.
Spieker, L. J., Box 347, Brainerd, Minn.
Summer, C. F., Jr., Box 401, R.F.D. 3, Turtle Creek, Pa.
Turner, W., 265 Ridgeway Ave., Rochester, N. Y.
Vacca, L. N., 43 Midland Pl., Newark 6, N. J.
Wilson, G. G., 2858 E. 194 St., New York 61, N. Y.
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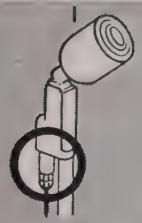

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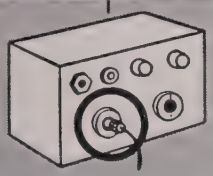
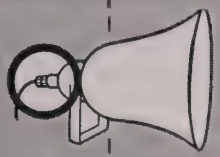


AMPLIFIERS



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Positions Wanted

(Continued from page 54A)

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Young, hard hitting research and design engineer seeks inquiries from firms needing addition to sales or field engineering staff. Desires change to position which will allow combination of engineering and top sales talents. Have solid experience in all phases of electronics and communications. Also quality control and teaching experience along with B.E.E. degree. Married, 1 child. Will consider Baltimore, Md. or vicinity. Box 226 W.

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Strong technical background, good sales personality. Desires position in New York City vicinity. Box 227 W.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 28A)

of the three voltage pedestals produced by the photocell is amplified in a common amplifier circuit and then applied to the vertical deflection plates of an oscilloscope. The sweep voltage is applied to the horizontal plates of the oscilloscope in such a manner that termination of each viewing cycle occurs at the same time that the scanning disk alternates from one aperture to another.

The indications of the three voltage pedestals appear as three horizontal lines on the face of the oscilloscope due to the persistence of the screen, combined with a rapid scanning rate.

New Wide Range Logarithmic Attenuator

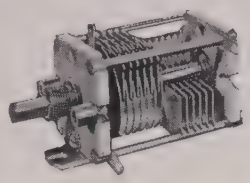
The Kay-Lab Logaten, a wide-range logarithmic attenuator with an output proportional to the logarithm of its input for a range of 50 db, has been developed by **Kalbfell Laboratories, Inc.,** Dept. P, 1076 Morena Blvd., San Diego 10, Calif.

Frequency response of the attenuator is flat from dc to 500 kc, and only minor errors are found up to several megacycles. By plugging a Logaten into a vacuum-tube voltmeter, oscilloscope, or recorder, these devices can be made to read linearly in decibels. In its octal-plug form, the Logaten is suitable for inclusion in amplifiers. It is adaptable to many applications involving electronic computers through the well-known principle of multiplication and division by logarithms. It also finds application wherever data having a very great dynamic range must be recorded on a single sensitivity range of an instrument. In acoustical reverberation studies, it converts the ordinary exponential decay curve into a straight line.

The Logaten is a network of nonlinear circuit elements adjusted to give an output voltage which is accurately proportional to the logarithm of input voltage. Both input and output impedances are 10,000 ohms. Its case is $1\frac{1}{2}$" in diameter by $2\frac{3}{4}$" long.

(Continued on page 56A)

end Fluctuations in Capacity



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Subject them to the toughest service, and JOHNSON'S new Type L Variables "come up" smiling—continue to maintain capacities and deliver peak performance!

Thanks go to JOHNSON'S use of perfected ceramic soldering which by eliminating the need for eyelets, nuts and screws, also eliminates possibility of stator wobble and fluctuations in capacities.

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DIFFERENTIAL TYPE—Available in three models: 2.8 to 11 mmf, 3.5 to 27 mmf, 4.6 to 51 mmf.

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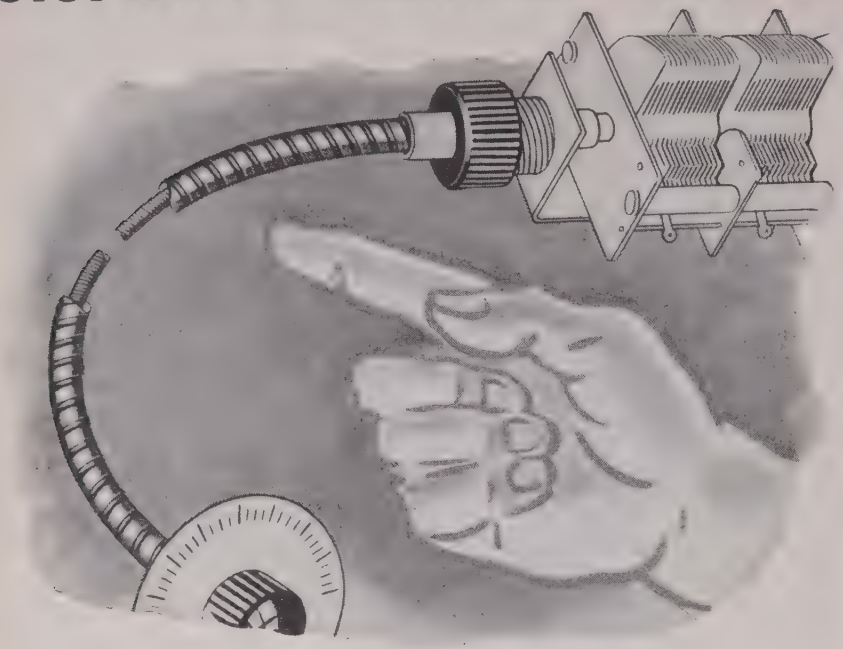

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 55A)

New Catalogs

• • • A new loose-leaf catalog illustrating relays, transformers, coils, terminals, etc., has just been released and is available without cost to those who inquire on their firm stationery, from **Comar Electric Co.,** 2701 Belmont Ave., Chicago 18, Ill.

• • • In September, 1948, this column published an item describing the Twin-Trax Recorder manufactured by **Amplifier Corp. of America,** 398-1 Broadway, New York 13, N. Y. Now this firm is offering a 12-page booklet compiled from an analysis of 5,000 letters answering the most-often-asked questions about the recorder. Entitled "99 Questions," this folder will be sent free on request.

• • • A folder on mechanical development apparatus for laboratory and developmen engineers has been released by a new firm, **Servomechanisms, Inc.,** Old Country & Glen Cove Rds., Mineola, L. I., N. Y.

• • • A six page folder in color describing various mounts for antenna installation by **Metalace Corp.,** 2101 Grand Concourse Bronx, 35, New York.

(Continued on page 57A)

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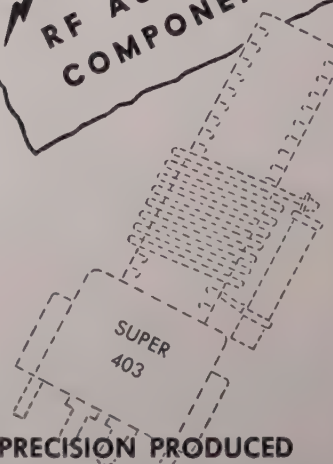

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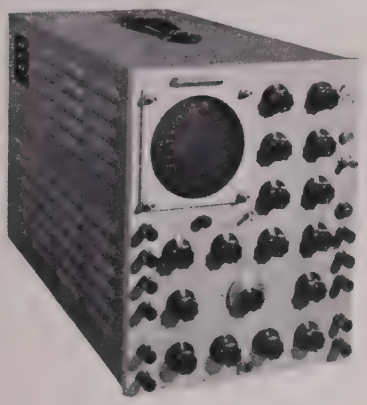

Tektronix Type 511-AD Oscilloscope
$845 f.o.b. Portland

Wide Band, Fast Sweeps

The **Type 511-AD,** *with its 10 mc. amplifier, 0.25 microsecond video delay line and sweeps as fast as .1 microsec./cm. is excellent for the observation of pulses and high speed transient phenomena. Sweeps as slow as .01 sec./cm. enable the 511-AD to perform superlatively as a conventional oscilloscope.*

Tektronix Type 512 Oscilloscope
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Direct Coupled, Slow Sweeps

The **Type 512** *with a sensitivity of 5 mv./cm. DC and sweeps as slow as .3 sec./cm. solves many problems confronting workers in the fields where comparatively slow phenomena must be observed. Vertical amplifier bandwidth of 1 mc. and sweeps as fast as 3 microsec./cm. make it an excellent general purpose oscilloscope as well.*

Both Instruments Feature:

- *Direct reading sweep speed dials.*
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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 56A)

New Microwave Power Meter

A new microwave power meter, known as the - hp-430A, designed to automatically indicate power developed in a standard barreter, is now being marketed by **Hewlett Packard Co.,** 395 Page Mill Rd., Palo Alto, Calif.

Power level is read directly on a 4″ square meter face. No calculation or knob-twisting is necessary once range selection and zero set are made. The -hp- 430A is automatically self-balancing, and may be used over any frequency, depending on the associated barreter and mount.

This meter consists of an ac bridge, one arm of which is a barreter. The bridge is in balance with zero rf power in the barreter. As rf power is applied to the barreter, an equivalent ac (audio) power is automatically removed. Thus the bridge remains in balance. A vacuum-tube voltmeter reads the change in audio power level. This meter, calibrated in milliwatts, gives a direct indication of the rf power in the barreter.

The indicating meter is calibrated in dbm in addition to the linear milliwatt calibration.

The five power ranges are selected on a convenient front-panel switch.

From a technical standpoint, the -hp 430A covers a power range of from 0.02 to 10 milliwatts. Ranges are related in 5-db steps, and continuous readings are available from −20 dbm to +10 dbm (0 dbm equals 0.001 watt). This power range may be extended by the use of attenuators or directional couplers. Accuracy of the meter is within ±5% of full-scale readings.

The -hp- 430A microwave power meter measures 12″ wide by 9″ high, and is 9″ deep. It is powered by a 115-volt 60-cps ac source.

New Beta-Gamma Counter

An aluminum beta-gamma counter, RMA type designation 1B85, designed to replace the thin-walled glass tubes previously used in laboratory and field radiation-measuring instruments, was placed on the market a few months ago by **The Victoreen Instrument Co.,** 5608 Hough Ave., Cleveland 3, Ohio.

(Continued on page 58A)

A quick reference on 433 PRACTICAL ELECTRONIC CIRCUITS

• with full diagrams and data for each one

WHETHER you want to brush up on the wiring system of a five-hundred-watt ultrasonic generator circuit or need complete information on a circuit for detecting either metallic or non-metallic objects—you'll find all the answers in the pages of this handy manual. It contains all types of circuits—from counting to welding control, both simple and advanced. It brings you hundreds of industrial circuits developed during the war when research and practical improvements hit an all-time high.

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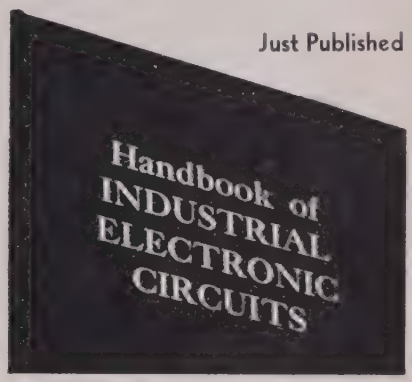

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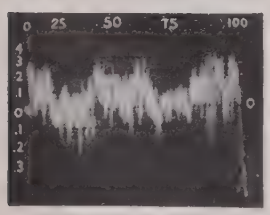

FIGURE 1. Cathode Ray oscillograph showing percentage error of standard potentiometer after one million cycles or two million sweeps of phosphor bronze contact over the wire. Initial linearity was ± .17% and the error increased to ± .28% plus noise.

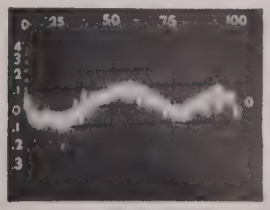

FIGURE 2. Shows performance of modified potentiometer after one million cycles or two million sweeps of PALINEY #7 contact over wire. The initial error was reduced to ± .12% and this linearity was maintained throughout the test.

RESULTS OF LIFE TESTS on nickel-chrome wire-wound potentiometers using contacts of PALINEY #7 in comparison with phosphor bronze.

Tests were made on a potentiometer equipped with a phosphor bronze contact in comparison with the same type potentiometer with a PALINEY #7 precious metal contact. Error measurements were made on a special tester equipped with cathode ray tube calibrated to measure directly in percentage of error.

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

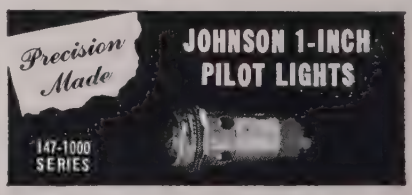
(Continued from page 57A)

The thyrode 1B85 operates at 900 volts. The plateau length is not less than 200 volts, and the plateau slope does not

exceed 3% per 100 volts. Nominal recovery time is 100 microseconds. The minimum operating life is 10^8 counts per minute with life-test end-point plateau 850 to 950 volts. The wall of 30 mg/cm² aluminum provides greater uniformity.

The new design features claimed by the manufacturer are: more nearly uniform and reproducable characteristics; plug-in base for practical water-tight probe or chassis mounting; and ribbed walls for greater mechanical strength.

(Continued on page 60A)



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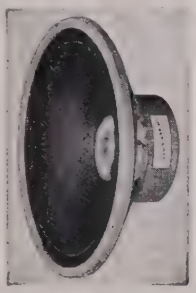

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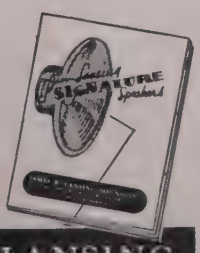

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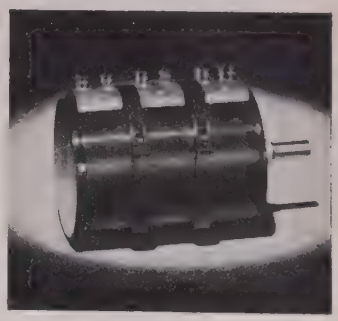

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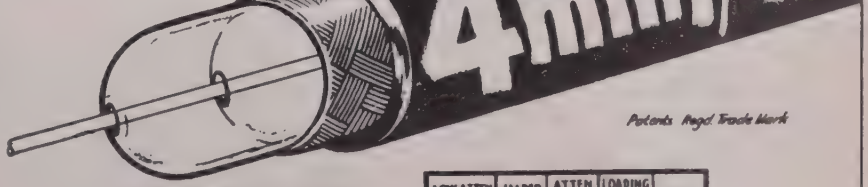

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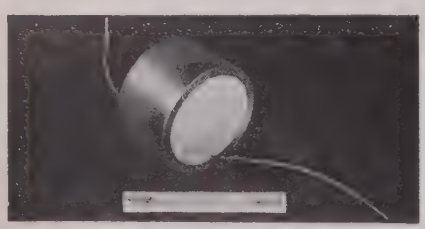

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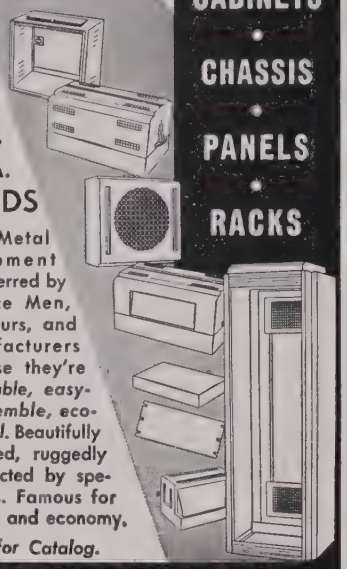

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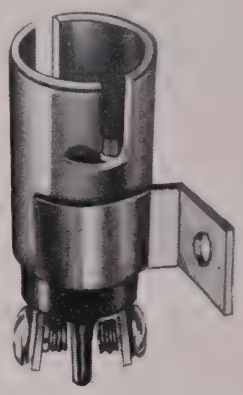
(Continued from page 58A)

Beaver Construction Socke for GE Pilot Lamp

For those companies using the GE 1 watt 115-volt double-contact bayonet-ba pilot lamp, the **Cole-Hersee Co.**, 20 O Colony Ave., Boston 27, Mass., recon



mends their new beaver constructio socket, rather than one of wafer constru tion, because a wafer will not make prop contact if the two solder spots on the ba of the lamp are not exactly the sam height.

(Continued on page 61A)

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(Continued from page 60A)

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• • •Two bulletins: No. 83, which describes rf inductors for broadcast phasing and tuning networks, and No. 85, which explains the type 1900 automatic dehydrator for use on coaxial transmission-line systems, may be obtained from **Andrew Corp.,** 363 E. 75th St., Chicago 19, Ill.

• • •Two bulletins, No. 485, describing the models LS100 and LS1000 decade-scaling laboratory counter sets, and No. 486, describing the model SM3 portable radiation survey meter, by **El-Tronics, Inc.,** 2647 N. Howard St., Philadelphia 33, Pa.

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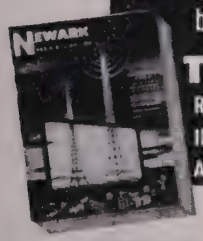

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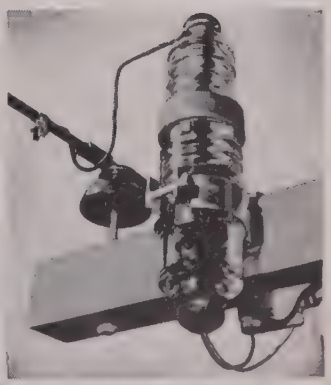

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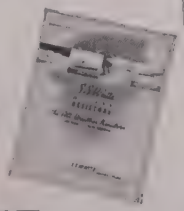

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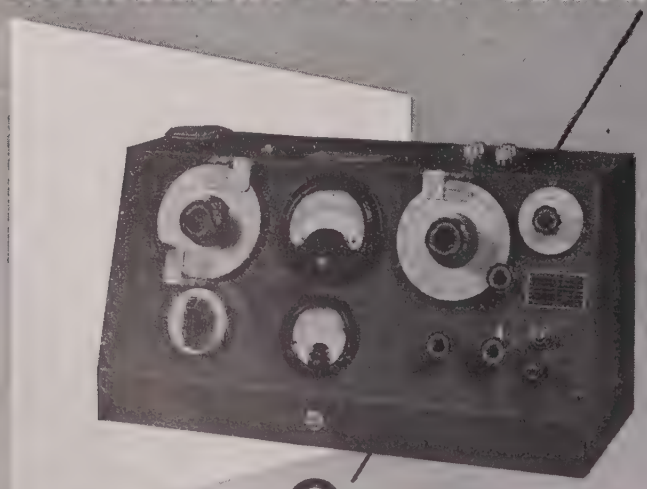

160-A Q METER

The 160-A Q-Meter is unexcelled for laboratory and development applications, having received world wide recognition as the outstanding instrument for measuring Q, inductance, and capacitance at radio frequencies.

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Range of Vernier Q Capacitor: +3 mmf., zero, —3 mmf.

For further specifications and descriptive details, write for Catalog F

BOONTON RADIO Corporation
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INDEX AND DISPLAY ADVERTISERS

Section Meetings 34A
Student Branch Meetings 38A
Membership 40A
Positions Open 50A
Positions Wanted 52A
News—New Products 28A

DISPLAY ADVERTISERS

Acme Electric Corporation 49A
Aircraft Radio Corp. 48A
Allen-Bradley Co. 39A
American Lava Corp. 15A
Arnold Engineering Co. 26A
Arrow Electronics, Inc. 60A
Astatic Corporation 40A
Audio Development Co. 34A

Bell Telephone Labs. 3A
Bendix Aviation Corp. (Radio Div.) 51A
Bliley Electric Co. 28A
Boonton Radio Corp. 62A
W. J. Brown 63A
Browning Laboratories, Inc. 45A
Bud Radio, Inc. 38A

Cambridge Thermionic Corp. 49A
Cannon Electric Dev. Co. 55A
Capitol Radio Eng. Inst. 53A
Centralab ..... 10A, & 11A, 41A
Cleveland Container Co. 30A
Sigmund Cohn Corp. 49A
Communications Equipment Co. 47A
E. J. Content 63A
Continental Carbon, Inc. 63A
Cornell-Dubilier Electric Corp. ..... Cover III
Crosby Labs. 63A

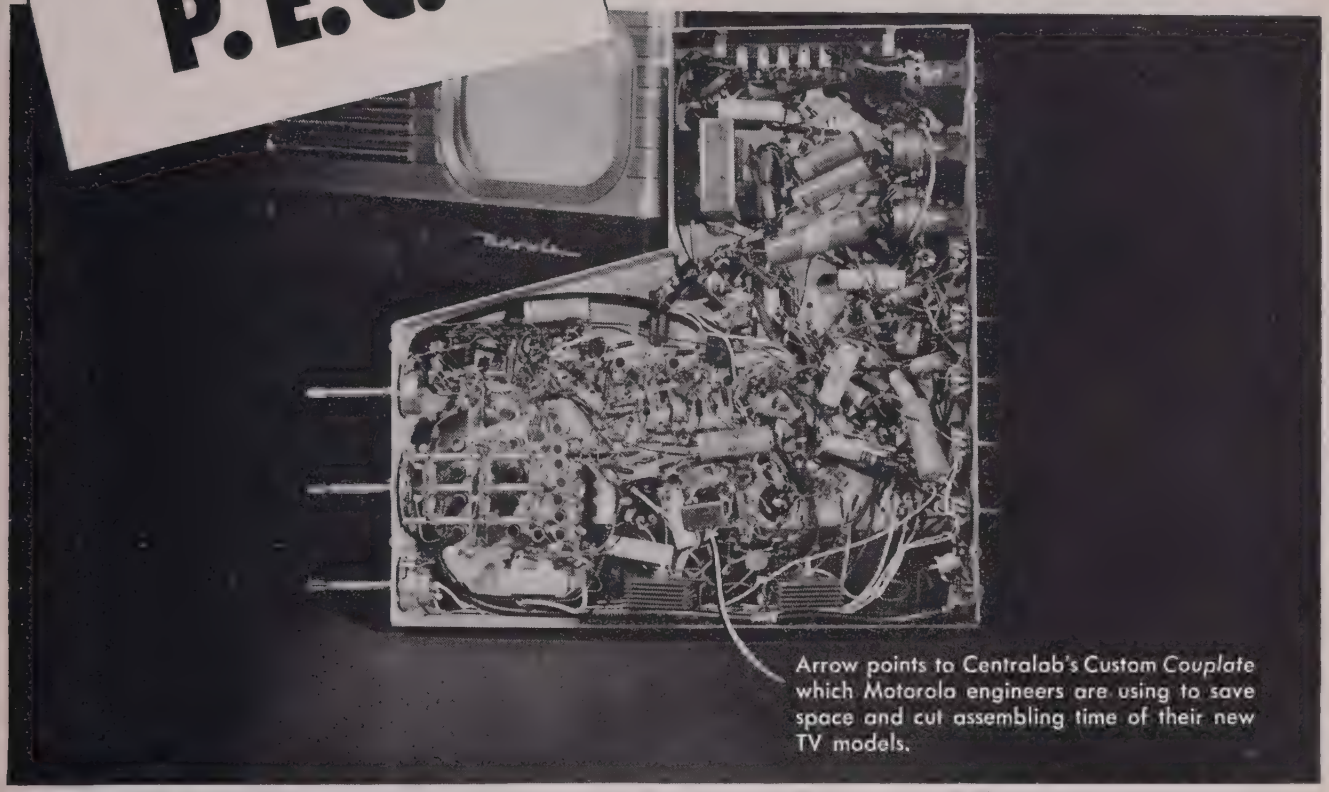
Daven Co. 46A
Allen B. DuMont Laboratories, Inc. 35A

Eitel-McCullough, Inc. 7A
Electrical Reactance Corp. 17A
Electro-Motive Mfg. Co., Inc. 23A
Electro-Voice, Inc. 42A

Federal Telecommunication Labs. 51A
W. L. Foss 63A
Freed Transformer Co., Inc. 21A
Furst Electronics 58A

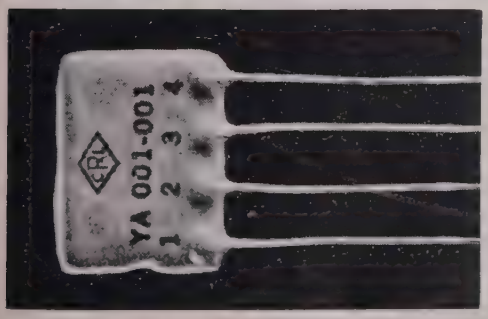
PROGRESS REPORT ON P.E.C.*

How Motorola is using Centralab's "P. E. C." to help build more and finer television receivers than ever before!

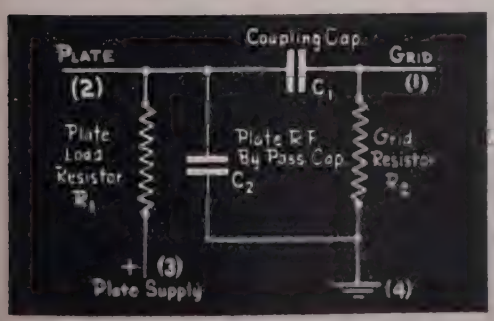


Arrow points to Centralab's Custom *Couplate* which Motorola engineers are using to save space and cut assembling time of their new TV models.

Chassis courtesy of Motorola Corp.



"COUPLATE" is made of high dielectric Ceramic X to give long life, low internal inductance, positive resistance to humidity and vibration. A circuit diagram of CRL's *Couplate* is shown below.



*Centralab's "Printed Electronic Circuit" — Industry's newest method for improving design and manufacturing efficiency!

SPEEDED production and finer products go hand in hand where Centralab's amazing *Printed Electronic Circuit* is concerned. Take the case of Motorola's new television receivers. Engineers for Motorola find that CRL's *Couplate* — a printed interstage coupling plate — saves production time by cutting in half the number of connections to be soldered . . . that it speeds assembly by simplifying wiring operations. They also find that *Couplate* helps them produce finer TV receivers by practically eliminating loose or broken connections — from plate load resistor to coupling capacitor.

Integral Ceramic Construction: Each *Printed Electronic Circuit* is an integral assembly of *Hi-Kap* capacitors and resistors closely bonded to a steatite ceramic plate and mutually connected by means of metallic silver paths "printed" on the base plate.

For complete information about Couplate as well as other CRL *Printed Electronic Circuits*, see your nearest Centralab representative, or write direct.

LOOK TO **Centralab** IN 1949!

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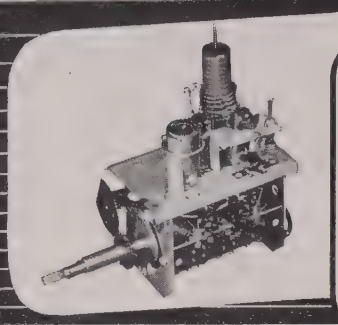
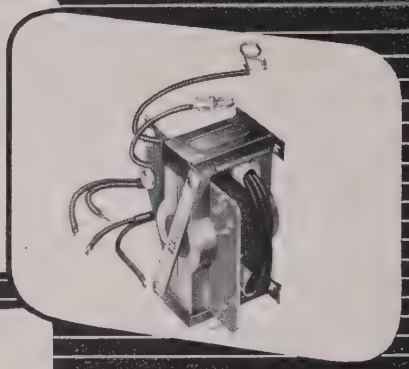
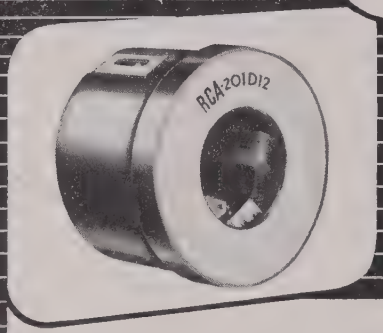
RCA TELEVISION COMPONENTS

THE STANDARDS OF THE INDUSTRY







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✓ A complete line of major components
✓ Highest quality . . . competitively priced
✓ Designed by RCA television engineers
✓ Available for immediate delivery

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RCA's line of television components is performance proved and competitively priced. As a result of increased manufacturing facilities, these components are now available in quantity for immediate delivery.

RCA's long experience in the design of television equipment is your assurance of *better* television components now and in the future.

RCA Application Engineers are ready to co-operate with you in the adaptation of RCA television components to your special receiver designs.

• • •

For other information write RCA, Commercial Engineering Section 47ES, Harrison, N. J., or telephone:

(EAST) Harrison 6-8000, Harrison, N. J.
(MIDWEST) Whitehall 4-2900, Chicago, Ill.
(WEST) Trinity 5641, Los Angeles, Calif.

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RADIO CORPORATION of AMERICA
ELECTRONIC COMPONENTS HARRISON, N. J.

SECTION MEETINGS

ATLANTA

"The Transistor," by W. H. Brattain, Bell Telephone Laboratories; January 21, 1949.

Election of Officers; January 21, 1949.

"Electronic Arithmetic," by C. N. Hoyler, RCA Laboratories, Princeton, N. J.; February 25, 1949.

BALTIMORE

"The Transistor," by J. N. Shive, Bell Telephone Laboratories; February 23, 1949.

BUFFALO-NIAGARA

"A High-Quality Loudspeaker System," by R. T. Bozak (formerly, Wurlitzer Company) January 19, 1949.

CEDAR RAPIDS

"What Kind of Engineers," by J. D. Ryder, Iowa State College; January 19, 1949.

"Annual Report," by T. A. Hunter, Regional Director of Region 5; January 19, 1949.

Election of Officers; January 19, 1949.

"An Analysis of Distortion Resulting from Two-Path Propagation," by I. H. Gerks, Collins Radio Company; February 16, 1949.

"A Low-Drag Aircraft Antenna for Reception of Omnidirectional Range Signals in the 108 M to 122 M Band," by J. P. Shanklin, Collins Radio Company; February 16, 1949.

CHICAGO

"The Radio Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; January 21, 1949.

"Sensory-Prosthesis," by N. Wiener, Massachusetts Institute of Technology; February 18, 1949.

CINCINNATI

"The Airborne Transponder," by L. B. Hallman, Jr., Wrightfield Communication & Navigation Laboratory; February 15, 1949.

CLEVELAND

"The Transistor, A New Semiconductor Amplifier," by J. N. Shive, Bell Telephone Laboratories; March 17, 1949.

CONNECTICUT VALLEY

"New Developments in Cathode-Ray Test Equipment," by W. G. Fockler, A. B. DuMont Laboratories; February 17, 1949.

DALLAS-FORT WORTH

"A Consideration of the Factors Affecting the Design of Turnstile Antennas," by G. H. Brown, RCA Laboratories, Princeton, N. J.; February 23, 1949.

DAYTON

"Meteors and the Earth's Upper Atmosphere," by F. L. Whipple, Harvard College Observatory; March 5, 1949.

DENVER

"Cyclotrons and Atom Smashing," by D. B. Harris, Collins Radio Company; March 3, 1949.

Election of officers; March 3, 1949.

DETROIT

"The Role of Electronics in Nucleonics," by I. H. McLaren, Bendix Aviation Research Laboratories; February 18, 1949.

INDIANAPOLIS

"Intercarrier Sound Systems for Television," by S. W. Seeley, Radio Corporation of America; January 28, 1949.

"Xerography (Electrophotography)," by I. M. Slater, P. R. Mallory & Company, Inc.; February 25, 1949.

(Continued on page 36A)

COSMALITE

in STANDARD COIL PRODUCTS CO. TUNERS

Of course COSMALITE is used by the STANDARD COIL PRODUCTS CO., INC. in their Television and Auto Set Tuning Assemblies. It is the first choice of those who insist on precision and quality products at prices that are right!

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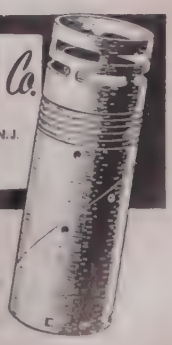

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Although relatively low in cost, these B & W instruments meet the exacting demands of modern research and engineering laboratories, as well as the full indorsement of many well-known broadcast stations. They combine a high degree of accuracy with outstanding durability and ease of use.

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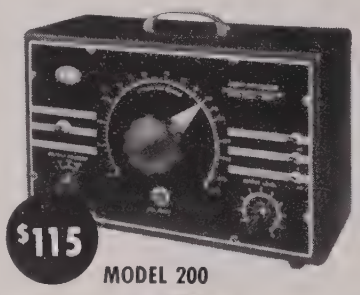
Provides an extremely low distortion source of frequencies between 30 and 30,000 cycles. Self-contained power supply. Calibration accuracy of ±3% scale reading. Stability 1% or better. Frequency characteristics: output flat within ±1 DB, 30 to 15,000 C.P.S. Size 13¾" x 7¼" x 9½" Fully portable.



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An ideal instrument for either laboratory or field use. Measures total harmonic distortion for the range of 50 to 15,000 cycles, and measures harmonics to 45,000 cycles. Also measures residual hum and noise up to 60 DB below any reference level. Voltmeter and DB meter range is from 30 to 30,000 cycles. Highly sensitive and accurate. Size 13¾" x 7¼" x 9½".

$140 MODEL 400

B & W FREQUENCY METER

An accurate and convenient means of making direct measurements of unknown frequencies up to 30,000 cycles. Useful in measuring beat frequency between two R.F. signals. Integral power supply. Handy for routine checking of audio oscillators or tone generators. Highly sensitive, this unit will operate on any wave form with peak ratios under 8 to 1. Size 13¾" x 7¼" x 9½".

$105 MODEL 300

WRITE FOR B & W CATALOG SUPPLEMENT NO. 1 . . . containing full details on these and other B & W instruments and electronic specialties.

BARKER & WILLIAMSON, INC.

Dept. PR-59, 237 Fairfield Ave., Upper Darby, Pa.

SECTION MEETINGS

(Continued from page 34A)

LOS ANGELES

"Kinescope Recording," by L. D. Grignon, Twentieth Century Fox Film Corporation and R. M. Fraser, National Broadcasting Company; February 15, 1949.

"Radio—The Hard Way," by G. R. Sams, U. S. Navy Air Missile Test Station; February 15, 1949.

LOUISVILLE

"Tunnel Oscillator," by H. R. Warren, Girdler Corporation; March 11, 1949.

"Radio Aids to Air Navigation," by P. Glasscoe, Civil Aeronautics Administration; February 11, 1949.

NEW MEXICO

"The Transistor," by R. B. Gibney, Los Alamos Scientific Laboratory; February 18, 1949.

OTTAWA

"Receiving Tube Performance at Ultra-High Frequencies," by J. A. Loutit, Canadian Army; February 24, 1949.

PHILADELPHIA

"Some Recent Developments in the Application of Germanium Crystals," by S. T. Martin; Sylvania Electric Products Inc.; March 3, 1949.

PRINCETON

"The Reduction of Common Channel and Multipath Interference by Special FM Receiver Design," by L. B. Arguimbau, and J. Granlund, Massachusetts Institute of Technology; February 10, 1949.

SACRAMENTO

"Stratovision Television," by J. H. Landells, Westinghouse Electric Company; February 8, 1949.

ST. LOUIS

"Stratovision—Airborne Television and FM Broadcasting," by C. E. Nobles, Westinghouse Electric Company; January 27, 1949.

SAN DIEGO

"Design of Regulated Power Supplies," by D. C. Kalbfell, Kalbfell Laboratories Inc.; March 1, 1949.

SALT LAKE

"The Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; February 11, 1949.

SAN ANTONIO

Election of Officers; January 20, 1949.

SAN FRANCISCO

"Experimental Television at 600 Mc," by L. M. Reed and C. N. Winningstad, Television; February 9, 1949.

SEATTLE

"Television Equipment," by J. Frost, Engineering Products Division, RCA, America; January 25, 1949.

TOLEDO

"The Radio Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; February 28, 1949.

TORONTO

"Microwave Relaying," by J. McLean, Philco Corporation; January 24, 1949.

"Television Test Equipment," by C. W. Finnegan, Stromberg-Carlson; February 7, 1949.

WASHINGTON

"Fundamental Limitations of Wide-Band Amplifiers," by H. A. Wheeler, Wheeler Laboratories, Inc.; January 10, 1949.

(Continued on page 37A)

SECTION MEETINGS

(Continued from page 36A)

"Twenty Year's Progress in Radio Diriction Finding," by R. L. Smith-Rose, Junior Past Vice-President of the IRE; March 14, 1949.

"A Circuit Which Picks the Peak of a Low-Frequency Asymmetrical Wave," M. J. Parker, Naval Ordnance Laboratory; February 14, 1949.

"Low-Frequency Synchronized Sawtooth Generator Providing Constant Amplitude Sweep with a Periodic Synchronization Input," P. Yaffee, Naval Ordnance Laboratory; February 14, 1949.

SUBSECTIONS

AMARILLO-LUBBOCK

"New Developments in the VHF Band," by G. F. Reed and J. S. Stover, General Electric Company and Communications Engineering Company, respectively; February 16, 1949.

HAMILTON

"Factors Underlying Reproduction of Sound," by H. Goldin, Gaumont-Kalee Ltd.; March 14, 1949.

LANCASTER

"Contribution of Electricity to the Safety of Air Navigation," by W. L. Anderson, Pennsylvania Aeronautics Commission; February 17, 1949.

"Some Recent Developments in the Application of Germanium Crystals," by S. T. Martin, Sylvania Electric Products Inc.; March 2, 1949.

LONG ISLAND

"The Traveling-Wave Tube and Other Electron Beam Amplifier Tubes," by R. G. E. Hutter, Sylvania Electric Products Inc.; January 26, 1949.

MONMOUTH

"Television Receiving Antennas," by D. C. Gleckner and A. E. Joost, Antenna Research Laboratory, Inc.; February 16, 1949.

NORTHERN NEW JERSEY

"Infrared Electron Telescopes," by G. L. Krieger, RCA Laboratories, Princeton, N. J.; February 9, 1949.

"Three-Speed Magnetic Tape Recording," by R. H. Ranger, Rangertone Inc.; February 9, 1949.

STUDENT BRANCH MEETINGS

ALABAMA POLYTECHNIC INSTITUTE—IRE BRANCH

"Dynamic Noise Suppressors," by R. M. Steere, Associate Professor, Alabama Polytechnic Institute; January 31, 1949.

Election of Officers January 31, 1949.

"Radar," by C. Cadell, Student; February 14, 1949.

UNIVERSITY OF ALBERTA—IRE BRANCH

"The Position of the Engineer in Society," by Mr. McDougall, Registrar of the Association of Professional Engineers of Alberta; February 22, 1949.

CALIFORNIA STATE POLYTECHNIC COLLEGE—IRE BRANCH

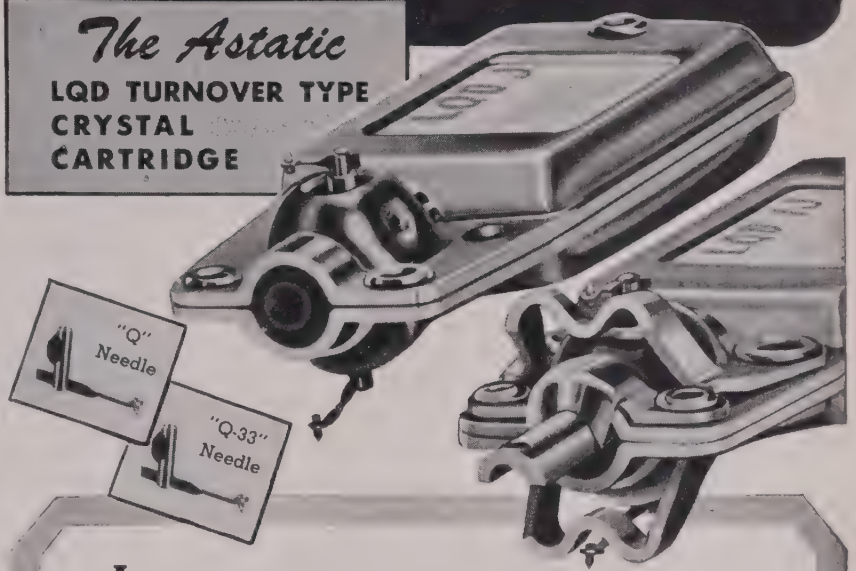
"Instruments in Industry," by H. M. Whittenton, General Electric Company; February 23, 1949.

(Continued on page 38A)

A DOUBLE-NEEDLE PICKUP CARTRIDGE

with Top Quality Performance Characteristics *plus* the most convenient needle replacement arrangement that has been devised.

The Astatic
LQD TURNOVER TYPE CRYSTAL CARTRIDGE



A GENTLE PRY with penknife or screw driver, and ONE needle comes out of the Astatic LQD Double-Needle Cartridge when replacement is necessary . . . without disturbing the other needle, without removing cartridge from tone arm, without so much as the turn of a screw or use of other tools. Gentle pressure with the tip of a knife blade snaps the new needle into place. This simple arrangement has spearheaded a resounding welcome by large users for Astatic's new LQD Cartridge. Astatic type "Q" Needle, with three mil tip-radius, and "Q-33," with one mil tip-radius, are employed . . . established types which have been on the market for some time and are readily available. The relatively high vertical and lateral compliance of this needle design affords appreciable reduction in needle talk, contributing greatly to the new cartridge's high standard of reproduction.

Listening tests by prospective users have prompted such comments as: "Unquestionably the best we've heard." You are urged to make your own comparisons, note the excellent frequency response particularly at low frequencies, judge for yourself the performance qualities and convenient utility of the Astatic LQD Double-Needle Cartridge. Available with or without needle guards.

SPECIFICATIONS

1. Stamped aluminum housing.
2. Frequency response—50 to 7,000 c.p.s.
3. Output—1.2 volts (Audio-Tone Record, 78 RPM);
   .75 volts (Columbia 281 Record, 33⅓ RPM).
4. Recommended needle pressures—15 grams for 78 RPM and 6 to 8 grams for 33⅓ RPM.

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Astatic Crystal Devices manufactured under Brush Development Co. patents

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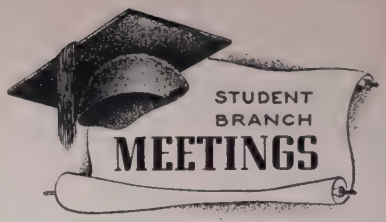


(Continued from page 37A)

COLLEGE OF THE CITY OF NEW YORK—IRE BRANCH

"The Coming Convention of the IRE," by E. K. Gannett, Assistant Secretary, The Institute of Radio Engineers; March 1, 1949.

"Quality Control in the Manufacturing of Components for Television," by L. Lutzker, Dumont Laboratories Inc.; March 15, 1949.

COLUMBIA UNIVERSITY—IRE-AIEE BRANCH

"Panel Discussion on Employment," by W. A. Curry, J. A. Balmford, W. LaPierre, L. O'Neill and L. Mason, staff members of the Electrical Engineering Department of Columbia University; March 4, 1949.

UNIVERSITY OF DAYTON—IRE BRANCH

"Composite Video Signals," by G. Share, Student; February 22, 1949.

UNIVERSITY OF FLORIDA—IRE-AIEE BRANCH

"Effective Bandwidth as a Measure of Noise Transmission Properties of Electrical Networks," by W. J. Kessler, Assistant Research Engineer, University of Florida; February 24, 1949.

"The Transistor, A New Semiconductor Amplifier," by J. A. Becker, Bell Telephone Laboratories; March 10, 1949.

THE GEORGE WASHINGTON UNIVERSITY—IRE BRANCH

"Radio Wave Propagation," by J. H. Dellinger, National Bureau of Standards; January 5, 1949.

UNIVERSITY OF ILLINOIS—IRE-AIEE BRANCH

"Hallmarks of an Engineer," by W. L. Everitt, Head of Electrical Engineering Department, University of Illinois; February 15, 1949.

IOWA STATE COLLEGE—IRE-AIEE BRANCH

"Industrial Electronics," by T. E. Johnty, General Electric Company; February 21, 1949.

"Mount Palomar Telescope," by L. B. Spinney, Professor of Physics, Iowa State College; March 2, 1949.

STATE UNIVERSITY OF IOWA—IRE BRANCH

"Forward Echo Ranging Transmission Systems," by D. Harris, Collins Radio Corporation; February 23, 1949.

LAFAYETTE COLLEGE—IRE-AIEE BRANCH

"Operation and Applications of Electrical Indicating Instruments," by L. F. Parachini, Weston Electrical Instrument Company; February 24, 1949.

UNIVERSITY OF MAINE—IRE-AIEE BRANCH

"FM Rebroadcasting," by R. W. Hodgkins, Guy Gannett Broadcasting Services; February 17, 1949.

MANHATTAN COLLEGE—IRE BRANCH

"High Fidelity Amplification," by H. T. Sterling, Instructor, Manhattan College; February 23, 1949.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY—IRE-AIEE BRANCH

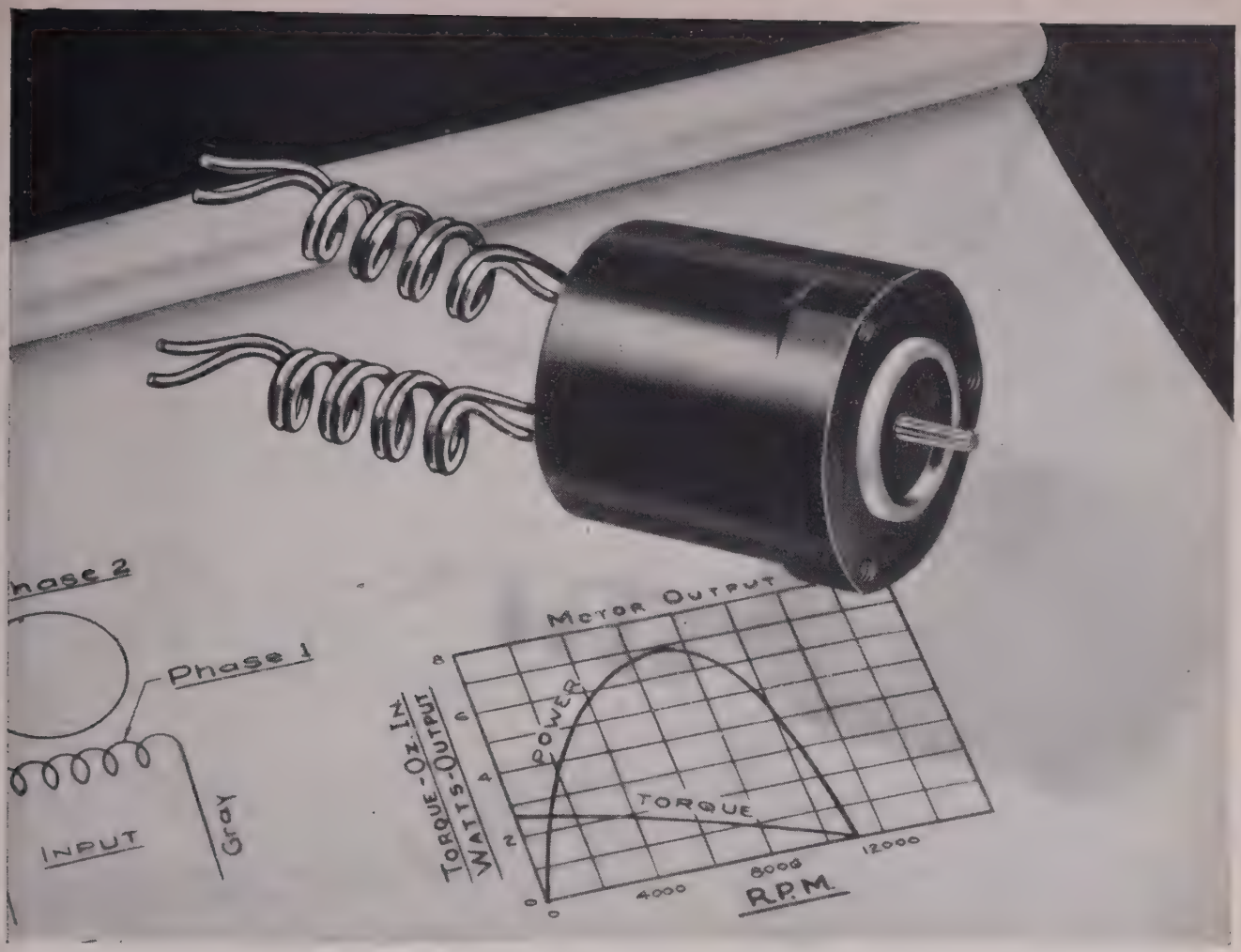
"Planning Your Career," by D. B. Smith, Philco Corporation; February 23, 1949.

MICHIGAN STATE COLLEGE—IRE-AIEE BRANCH

"Television and Microwave Relay," by W. Lawrence, Radio Corporation of America; February 23, 1949.

Election of Officers; March 9, 1949.

(Continued on page 40A)



A new low-inertia, high-torque motor by KOLLSMAN

This newest addition to the Kollsman line of special-purpose motors is a two-phase, low-inertia induction unit. It is designed for use in 400-cycle servo (null follow-up) systems which require a small motor with an unusually high torque/inertia ratio.

The Model 1318-0460 delivers maximum torque at stall, has a low moment of inertia and will not run single phase. Its frame is fully enclosed. Units with either plain or pinion shaft are available.

The Model 1318-0460 is but one of a complete line of special-purpose motors developed by Kollsman for remote indication and control applications. Complete information concerning any or all of these units is available by addressing: Kollsman Instrument Division, Square D Company, 80-08 45th Avenue, Elmhurst, N. Y.

Characteristics	
Frequency (c.p.s.)	400
Phases	2
Speed (r.p.m. — no load)	11,500
Torque (oz./in. — stalled)	2.5
Torque/inertia ratio (radians/sec./sec.)	26,340
Torque/inertia ratio (in. — oz./oz.—in.^{2})	68
Size (dia. x length)	1¾" x 1-47/64"
Weight (ounces)	6.1

KOLLSMAN INSTRUMENT DIVISION

SQUARE D COMPANY

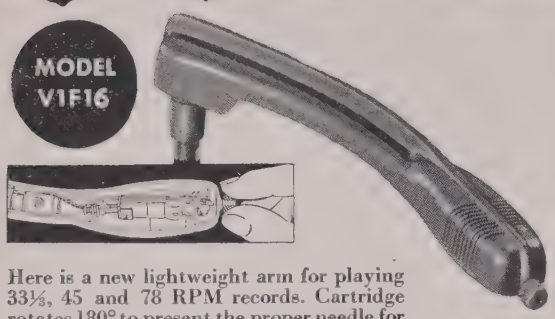
ELMHURST, NEW YORK GLENDALE, CALIFORNIA

WEBSTER ELECTRIC

Featheride TONE ARMS

That Meet the Requirements of 33⅓, 45 and 78 RPM Records

MODEL V1F16

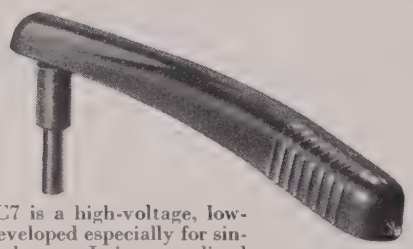


Here is a new lightweight arm for playing 33⅓, 45 and 78 RPM records. Cartridge rotates 180° to present the proper needle for standard or long-playing records, and locks in position. Tracking pressure is 7 grams in either position.
The illustration shows method of turning cartridge.

SPECIFICATIONS

APPLICATION: 33⅓, 45 and 78 RPM record players
NEEDLE Replaceable osmium-tipped. Single setscrew releases both needles
TRACKING PRESSURE: 7 grams on both needles
ARM CONSTRUCTION: Aluminum die-cast. Spring counterbalanced for 7 grams pressure
CARTRIDGE CONSTRUCTION: Stamped aluminum half shells with front bracket extending through front of pick-up arm to permit rotating the cartridge
TERMINALS: Pin type, grounded or ungrounded
OUTPUT: 1 volt, 1000 cps

MODEL T1C7

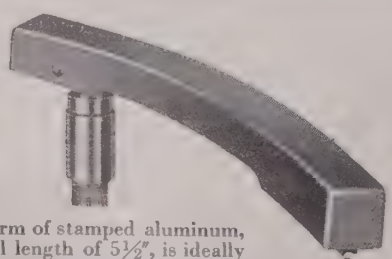


The Model T1C7 is a high-voltage, low-cost tone arm developed especially for single-play record players. It is streamlined in design and attractively finished. The rigid steel construction eliminates torque and resonance problems.

SPECIFICATIONS

APPLICATION: 78 RPM record players
TRACKING PRESSURE: 1¼ oz. minimum
OUTPUT: 3 volts, 1000 cps
ARM CONSTRUCTION: Stamped steel housing. Tinnerman fastening
COLOR: Antique copper tone
NEEDLE: Any standard type
LEAD WIRES: Plastic-covered—20 in.

MODEL BA-1

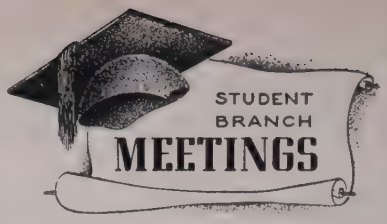


This new tone arm of stamped aluminum, with an over-all length of 5½", is ideally suited for use on player units designed for playing the new 7" records, either 33⅓ or 45 RPM. It incorporates the model A-1 miniature cartridge exerting a tracking pressure of only 7 grams without use of spring counterbalance.

SPECIFICATIONS

APPLICATIONS: 7" recordings (33⅓ or 45 RPM)
ARM CONSTRUCTION: Stamped aluminum
COLOR: Optional
CARTRIDGE CONSTRUCTION: Bakelite half shells
TERMINALS: Pin type
NEEDLES: Replaceable, osmium- or sapphire-tipped.
LEADS: Optional
TRACKING PRESSURE: 7 grams
OUTPUT: 1 volt, 1000 cps.

WEBSTER ELECTRIC
RACINE WISCONSIN
Established 1909
Export Dept. 13 E. 40th Street, New York (16), N. Y. Cable Address "ARLAB" New York City
"Where Quality is a Responsibility and Fair Dealing an Obligation"



(Continued from page 38)

UNIVERSITY OF MICHIGAN—IRE-AIEE BRANCH

"The Selective-Sequence Electronic Calculator," by H. R. J. Grosch, Columbia University; March 2, 1949.

MISSOURI SCHOOL OF MINES—IRE-AIEE BRANCH

"Electric Welding," by J. D. Vallier, General Electric Company; February 16, 1949.

"What the Electronic Engineer Can Expect of Industry," by W. Bennetsen, Emerson Electric Company; March 2, 1949.

UNIVERSITY OF NEBRASKA—IRE-AIEE BRANCH

"Demonstration of Magic," by Professor Westgate, University of Nebraska; March 2, 1949.

NEW YORK UNIVERSITY—IRE BRANCH

"The Engineer's Part in Television Broadcasting," by O. S. Freeman, Television Station WPIX; March 1, 1949.

"Ways and Means of Getting a Better Paying Job," by W. D. Ingham, Engineering Employment Service, Inc.; March 8, 1949.

PURDUE UNIVERSITY—IRE BRANCH

"Electronic Digital and Analogue Computers," by D. C. Ross, staff member, Purdue University; February 24, 1949.

ST. LOUIS UNIVERSITY—IRE BRANCH

"Presenting the Technical Report," by M. Cochran, staff member, St. Louis University; February 24, 1949.

STANFORD UNIVERSITY—IRE-AIEE BRANCH

"Through the Sonic Barrier," by W. G. Vincenti, Ames Laboratory; January 15, 1949.

"Carnival of Measurements," by J. M. Whittenton, General Electric Company; February 7, 1949.

TEXAS AGRICULTURAL & MECHANICAL COLLEGE —IRE-AIEE BRANCH

"D-C Calculator," by H. R. McKenzie, Student; March 3, 1949.

UNIVERSITY OF TOLEDO—IRE-AIEE BRANCH

"The Radio Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; February 28, 1949.

"Operation of a TV Transmitter," by W. Stringfellow, Radio Station WSPD-TV; March 16, 1949.

UNIVERSITY OF VIRGINIA—IRE-AIEE BRANCH

"Techniques of Cosmic-Ray Measurements Using Rockets," by C. Y. Johnson, Naval Research Laboratories; February 22, 1949.

WAYNE UNIVERSITY—IRE-AIEE BRANCH

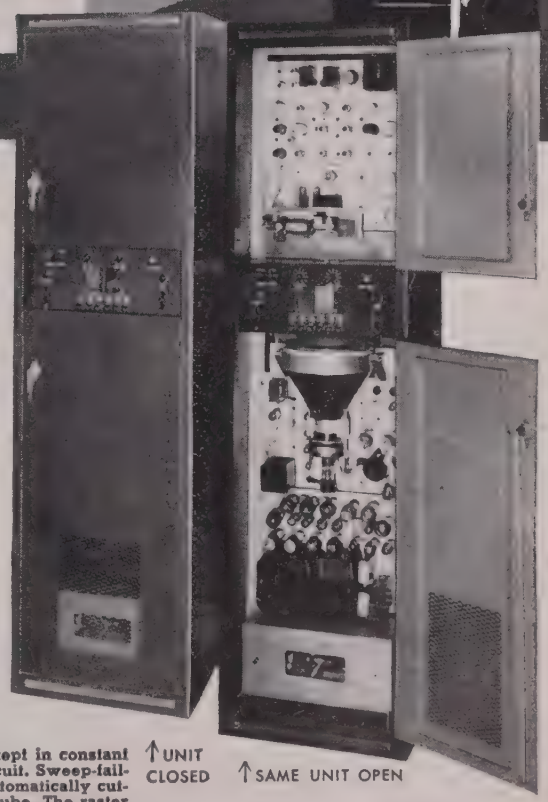
"D-C Control Circuits," by Mr. Lee, Department of Street Railways of Detroit; March 3, 1949.

Reduced studio operating budgets ...expanded program facilities... with the DU MONT MONOCHROME SCANNER Model TA-150-A ...

the magic lantern of TELECASTING!

$SD+QW=\frac{D}{FWFT}$

(Simple Translation)
SUPERIOR DESIGN plus
QUALITY WORKMANSHIP equals
DU MONT
First With the Finest in Television



↑UNIT CLOSED ↑SAME UNIT OPEN

Precisely, this latest Du Mont development, the Monochrome Scanner Model TA-150-A, is virtually "The Magic Lantern of Telecasting." It handles test patterns, commercials, station identification, still photographs, cartoons, graphs—any and all non-animated subjects in the only logical and really economical manner.

When driven from a sync generator such as the Du Mont Model TA-107-B, this unit develops an RMA standard composite signal from standard 2 x 2" glass slides. Still-image pickups become a simple, economical, one-man job. The need for costly film trailers and the operation of movie projectors for short bits, are minimized. The Monochrome Scanner soon pays for itself. Definitely, here's a "must" in the money-making telecast setup.

Early delivery predicated on previous orders

DU MONT MONOCHROME SCANNER Model TA-150-A

A short-persistence Du Mont 10" C-R tube produces a light beam focused by a projection lens on to the glass slide. A condenser lens focuses that light beam after passing through the slide, on to a multiplier-type photo-electric cell. The signal voltage developed is amplified and mixed with blanking and sync pulses, resulting in the RMA standard composite picture signal.

An automatic slide changer handles up to 25 positive or negative 2 x 2" glass slides, operated from local or remote position. The equipment houses the C-R tube and necessary circuits for producing a bright, sharply focused raster on the tube screen. The raster is kept in constant focus by the focus-stabilizer circuit. Sweep-failure protection is provided by automatically cutting off the high voltage to the tube. The raster is developed by sweep circuits driven by horizontal and vertical pulses.

A switch inserts sync if a composite signal is required, or leaves out the sync if only a video and blanking signal is required for video mixing purposes. Controls to set sync and blanking levels are provided. The control panel carries all necessary switches, fuses and fuse indicators. A fadeout switch sets the fading of the signal to black level when slides are changed for slow, medium or fast rate of change.

The unit is complete with its own high and low voltage power supplies. Operates on 115 v. 60 cycles. Approx. 8.0 amps.

Mounted in standard rack measuring 83½" h. x 22" w. x 18" deep.

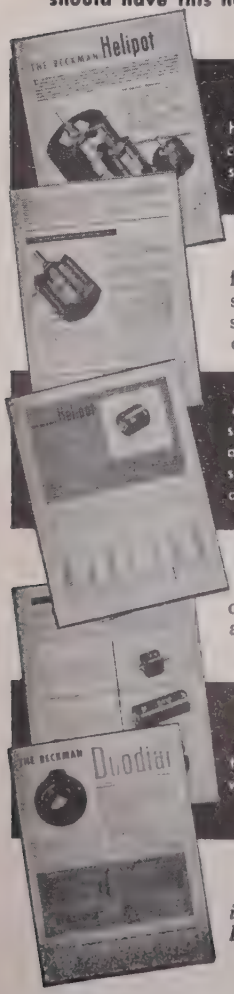
ALLEN B. DU MONT LABORATORIES, INC.

DUMONT *for Oscillography*

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U. S. A.

Do you have This Helpful Helipot *and* Duodial *Catalog?*

Do you have complete data on the revolutionary new *HELIPOT*—the helical potentiometer-rheostat that provides many times greater control accuracy *at no increase in panel space*?. . . or on the equally unique *DUODIAL* that greatly simplifies turns-indicating applications? If you are designing or manufacturing any type of precision electronic equipment, you should have this helpful catalog in your reference files . . .



It Explains – the unique helical principle of the HELIPOT that compacts almost four feet of precision slide wire into a case only 1¾ inches in diameter—over thirty-one feet of precision slide wire into a case only 3½ inches in diameter!

It Details – the precision construction features found in the HELIPOT . . . the centerless ground and polished stainless steel shafts—the *double* bearings that maintain rigid shaft alignment—the positive sliding contact assembly—and many other unique features.

It Illustrates – describes and gives full dimensional and electrical data on the many types of HELIPOTS that are available . . . from 3 turn, 1½" diameter sizes to 40 turn, 3" diameter sizes . . . 5 ohms to 500,000 ohms . . . 3 watts to 20 watts. Also Dual and Drum Potentiometers.

It Describes – and illustrates the various special HELIPOT designs available—double shaft extensions, multiple assemblies, integral dual units, etc.

It Gives – full details on the DUODIAL—the new type turns-indicating dial that is ideal for use with the HELIPOT as well as with many other multiple-turn devices, both electrical and mechanical.

If you use precision electronic components in your equipment and do not have a copy of this helpful Helipot Bulletin in your files, write today for your free copy.

THE Helipot CORPORATION, SOUTH PASADENA 6, CALIF.

The following transfers and admissions were approved and will be effective as of May 1, 1949:

Transfer to Senior Member

Ashbrook, F. M., 111-A Ellis St., China Lake, Calif.
Atwood, N. A., U.S.N., New York Naval Shipyard, Brooklyn 1, N. Y.
Bellare, D., 1245 E. Ninth St., Brooklyn 30, N. Y.
Condom Sastre, A., Calleb #56, Vedado, Havana, Cuba
DeSoto, C. B., 1 East 79 St., New York 21, N. Y.
Gegenheimer, W. C., 2402 Fairway Dr., Winston-Salem, N. C.
Jones, R. E., Mayo Clinic, Section on Engineering, Rochester, Minn.
Kennedy, E. D., Eng. & Indust. Experiment Station, University of Florida, Gainesville, Fla.
Kramer, A. W., 639 Lincoln St., Waltham, Mass.
MacAdam, W. K., 25 Bar Beach Rd., Port Washington, L. I., N. Y.
Maki, G. J., Box 1198, R.F.D. 7, Sacramento, Calif.
Massa, E. A., 28 Brookhouse Dr., Marblehead, Mass.
Pickering, W. H., California Institute of Technology, 1201 E. California, Pasadena 4, Calif.
Pierce, R. J., Box 2200, Honolulu, Hawaii
Price, W. E., 61 Nevada Ave., Haddonfield, N. J.
Shank, R. J., Florence Ave. at Teale St., Culver City, Calif.
Sherman, H., 348 Cedar Ave., Long Branch, N. J.
Speller, J. B., 154 Greenridge Ave., White Plains, N. Y.
Stewart, C., 51 Fort Dr., Alexandria, Va.
Summerhayes, H. R., Jr., 1212 Oxford Pl., Schenectady 8, N. Y.
Tittle, C. W., Box 5004, T. C. Station, Denton, Tex.
Toporeck, E. R., 104 B Forrestal, China Lake, Calif.
Wang, C. C., 223-20 65 Ave., Bayside, L. I., N. Y.
Wooldridge, A. C., 67 Prospect Ave., Montclair, N. J.

Admission to Senior Member

Bastedo, G. R., 24 Farragut Pl., N.W., Washington 11, D. C.
Callick, E. B., 1910 K St., N.W., Washington, D. C.
Davis, W. C., 4166 Ardmore Rd., South Euclid, Ohio
Gardiner, J. G., 1014 Madison Ave., Winston-Salem, N. C.
Hogan, C. M., 31 Merzen Ct., Cincinnati 17, Ohio
Sieger, J., Freed Radio Corp., 200 Hudson St., New York 13, N. Y.
Vos, M., Telefon AB L M Ericsson, Stockholm 32, Sweden
Wamsley, D. H., Radio Corporation of America, Lancaster, Pa.

Transfer to Member

Aristei, J., 749 Silver Spring Ave., Silver Spring, Md.
Bartlett, F. E., Radio Station KSO, Des Moines 9, Iowa
Boyer, B. E., 202 Via Alameda, Redondo Beach, Calif.
Chow, W. T., 141-30 Pershing Crescent, Jamaica 2, L. I., N. Y.
Coatney, A. E., 2106 Newton St., Columbus, Ind.
Coursey, J. R., 4700 Monarch St., Dallas 4, Tex.
DeBarro, F., 12, Rue Delta, Heliopolis, Egypt
French, I. F., 646 Humphrey St., Swampscott, Mass.
Gordon, W. E., Franklin Hall, Cornell University, Ithaca, N. Y.
Grdseloff, L., c/o Green's Commercial Agencies, P.O.B. 600, Cairo, Egypt
Hall, G. G., c/o Tecnico Ltd., Box 12, Marrickville, N.S.W., Australia

(Continued on page 44A)

For Accurate and Up-to-date News of Every British Development in Radio, Television and Electronics

WIRELESS WORLD is Britain's leading technical magazine in the general field of radio, television and electronics. For over 37 years it has consistently provided a complete and accurate survey of the newest British technique in design and manufacture. Articles of a high standard include reviews of equipment, broadcast receivers and components, while theoretical articles deal with design data and circuits for every application.

WIRELESS ENGINEER is read by research engineers, designers and students, and is accepted internationally as a source of information for advanced workers. The Editorial policy is to publish only original work, and representatives of the National Physical Laboratory, the British Broadcasting Corporation and the Engineering Department of the British Post Office are included on the Editorial Advisory Board.

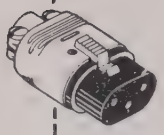
Subscriptions can be placed with British Publications Inc., 150 East 35th Street, New York. 16. N.Y., or sent direct by International Money Order to Dorset House, Stamford Street, London, S.E.1, England. Cables: "Iliffepres, Sedist, London."

ASSOCIATED ILIFFE PUBLICATIONS

ASSOCIATED TECHNICAL BOOKS: "Television Receiving Equipment" (2nd Edition), by W. T. Cocking, M.I.E.E. One of the most important British books on television. 13 shillings ($2.60); "Wireless Direction Finding" (4th Edition), by R. Keen, B.Eng. (Hons.), A.M.I.E.E. An up-to-date and comprehensive work on the subject. 45 shillings ($9.25); available from the British address above.

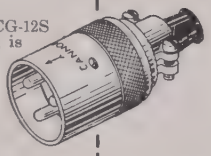
TYPE "O"

Type "O" Series—shown at right is the 03-11 Plug, with three 30-amp. contacts, fits certain quality types, notably Western Electric.



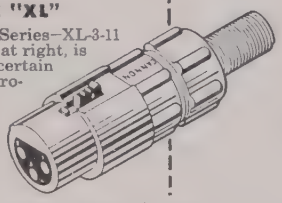
TYPE "P"

Type "P" Series—P3-CG-12S Plug shown at right, is standard with most broadcast stations and used with RCA and other equipment. . . 7 interchangeable inserts.



TYPE "XL"

Type "XL" Series—XL-3-11 Plug shown at right, is standard on certain RCA, Electro-Voice and Turner microphones. Two inserts: XL-3, XL-4.



Used on many types of sound and communication equipment in addition to microphone, *Cannon Plugs* are recognized by engineers, sound men and hams as the quality fittings in the field. Over a period of years various improvements have been made in insulating materials, shell design, material and clamp construction.

Available through many parts jobbers in the U. S. A. . . In *Louisville:* Peerless Electronic Equipment Co. In *Flint:* Shand Radio Specialties. In *Syracuse:* Morris Dist. Co. In *Toledo:* Warren Radio. In *Norfolk:* Radio Supply Co.

Bulletin PO-248 covers all the engineering data on the above 3 series; RJC-2 the prices; CED-8 Sheet lists jobbers. For copies address Department E-377.

SINCE 1915

CANNON ELECTRIC

CANNON ELECTRIC Development Company

3209 HUMBOLDT ST., LOS ANGELES 31, CALIF.

IN CANADA—CANNON ELECTRIC CO., LTD.

MEMBERSHIP

(Continued from page 42A)

Israel, L. J., U.S.A.F., Hdqs. 15 Air Force, Colorado Springs, Colo.
Kafafian, J., 1544 Union St., San Francisco 23, Calif.
Martin, J. L., 4226 W. 13 St., Amarillo, Tex.
McCarley, H. H., U. S. Navy, U.S.S. Hugh Purvis (DD708), c/o Fleet Post Office, New York, N. Y.
McLeod, J. W., 7549 S. Wabash Ave., Chicago 19, Ill.
Merchant, J. H., 2 Cedar St., Binghamton 47, N. Y.
Orwin, R. J., 4518 36 St. S., Arlington, Va.
Overmire, M. O., 12147 Huston St., North Hollywood, Calif.
Papenfuss, C. A. C., 6845 13 Ave., S., Minneapolis 19, Minn.
Parker, A. B., 3835 Voltaire St., San Diego 7, Calif.
Pattinson, T. H., 47, Rodenhurst Rd., London, S.W. 4, England
Richelieu, C. C., 23 Bennett Rd., Gardner, Mass.
Ruble, H. E., 3011 Athens Ave., Dayton 6, Ohio
Smith, D. P., Washington St., Sparkill, N. Y.
Stanton, L. J., 151 Eighth Ave., New York 11, N. Y.
Tschannen, R. F., 412 E. Maple St., Lombard, Ill.

Admission to Member

Acosta, R. J., #872 Cabrera St., Cabrera Urbanization, Rio Piedras, Puerto Rico
Arbuckle, F. M., RCA Princeton Laboratories, Princeton, N. J.
Bryson, H. C., Jr., 5428 Norfolk St., Philadelpha 43, Pa.
Covington, A. E., Box 388, Billings Bridge, Ont., Canada
Desi, G. R., Hazeltine Electronic Corp., Little Neck, L. I., N. Y.
Elliott, H. R., Apt. 3, 10 Bacon, Waltham 54, Mass.
Ferrara, G., 236 Withington Ave., Ferndale 20, Mich.
Ferre, M. D., Schlumberger Well Surveying Corp. Box 550, Old Quarry Rd., Ridgefield, Conn.
Fox, J. C., 2140 Alta, Louisville 5, Ky.
Godbey, J. K., 3120 Dutton Dr., Dallas 11, Tex.
Gustinelli, J. L., Vaubien, Orsay, Seine-et-Oise, France
Hayes, T. J., 36 N. Horton St., Dayton 3, Ohio
Hughes, R. W., 200 Lorraine Ave., Upper Montclair, N. J.
Johnson, R. R., Box 76, HAFB, c/o North American Aviation, Inc., Alamogordo, N. Mex.
Lescarbeau, R. F., 31 Suffolk Dr., East Hartford, Conn.
Matthews, R. D., R-145, Sandia Base Branch, Albuquerque, N. M.
Melhose, A. E., 635 Glen Ave., Westfield, N. J.
Morgan, H. L., 2312 El Cajon Blvd., San Diego 3, Calif.
Norris, W. E., 5401 Madison St., 2-C, Richmond, Calif.
Piecha, L. M., 2218 S. Leavitt St., Chicago, Ill.
Rao, K. L. N., Department of Radio Technology, S. J. Occupational Institute, Bangalore 1, India.
Rifkin, M. S., 144-46 69 Ave., Kew Gardens Hills, L. I., N. Y.
Roberts, G. A., 408 College Ave., Swarthmore, Pa.
Schlicke, H. M., 54 Juniper Rd., Port Washington, L. I., N. Y.
Simons, F. A., c/o CAA, International Services Division, A-36, Washington 25, D. C.
Tellez, J. M. B., 147 Aguascalientes, Mexico D. F., Mexico
Thompson, W C., Jr., B.O.Q. B-3, China Lake, Calif.
Tolbert, C. W., 502 Oakland, Austin, Tex.
Uslan, S. D., 2202 East 28 St., Brooklyn 29, N. Y.
Warner, A. H., 603 Essex Circle, China Lake, Calif.
Weber, M., 516 N. Adams St., Albuquerque, N. M.
Woodyard, O. C., 113 Atkins Ave., Neptune, N. J.

(Continued on page 45A)

MEASUREMENTS CORPORATION
Model 59

2.2 mc. to 400 mc.

MEGACYCLE METER

Radio's newest, multi-purpose instrument consisting of a grid-dip oscillator connected to its power supply by a flexible cord.

Check these applications:

- **For determining the resonant frequency of tuned circuits, antennas, transmission lines, by-pass condensers, chokes, coils.**
- **For measuring capacitance, inductance, Q, mutual inductance.**
- **For preliminary tracking and alignment of receivers.**
- **As an auxiliary signal generator; modulated or unmodulated.**
- **For antenna tuning and transmitter neutralizing, power off.**
- **For locating parasitic circuits and spurious resonances.**
- **As a low sensitivity receiver for signal tracing.**

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

SPECIFICATIONS:

Power Unit: 5⅛" wide; 6⅛" high; 7½" deep. Oscillator Unit: 3¾" diameter; 2" deep.

FREQUENCY:
2.2 mc. to 400 mc.; seven plug-in coils.

MODULATION:
CW or 120 cycles; or external.

POWER SUPPLY:
110-120 volts, 50-60 cycles; 20 watts.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

MEMBERSHIP

(Continued from page 44A)

The following admissions to Associate grade were approved to be effective as of April 1, 1949:

Alberts, H. C., 112-45 150 St., St. Albans 12, L. I., N. Y.
Alexander, R., c/o Sylvania Electric Products Inc., 40-22 Lawrence St., Flushing, L. I., N. Y.
Alston, W. H., 747 Webster Pl., Plainfield, N. J.
Alter, R. S., 59 Vreeland Ave., Clifton, N. J.
Aman, O. B., 49 W. 167 St., New York 52, N. Y.
Anderson, D. E., C.R.E.I., 16 St. and Park Rd. N.W., Washington 10, D. C.
Applebaum, A., 15 Elmira St., S.E., Washington 20, D. C.
Archer, L. A., 2300 W. Davis St., Dallas 11, Tex.
Arimura, T., 4436 S. Woodlawn Ave., Chicago 15 Ill.
Asdal, M. K., 463 Page Ave., Lyndhurst, N. J.
Atlee, R. Y., 50 Doyer Ave., White Plains, N. Y.
Bailey, E. M., 6 Home Ct., Stamford, Conn.
Baird, J. A., 38 Valley View Rd., Rockaway, N. J.
Bardsin, S., 1050 Stratford Ave., New York 59, N. Y.
Basole, G. M., 391, Sultan Bazar, Hyderabad, Hyderabad (DN), India
Baum, L., 634 Montgomery St., Brooklyn 25, N. Y.
Baumann, L. S., 525 Jennings Ave., Bridgeport 4, Conn.
Berardi, C. S., 3010 N. Washtenaw Ave., Chicago 18, Ill.
Beresford, D. R., 200 A Brynes, N.O.T.S., China Lake, Calif.
Berliner, J., 31 Cedar Ave., Apt. 29, West End, N. J.
Bernstein, B., 590 Clinton Ave., Newark 8, N. J.
Bestich, J. P., 4670 Grant St., Gary, Ind.
Billig, L. S., 140 Edgewater Apts., Essex 21, Md.
Bocchieri, A. J., 1504 Monroe St., Washington 10, D. C.
Bonney, H. W., 125-20 82 Ave., Kew Gardens 15, L. I., N. Y.
Boogers, N. H., 59 Gresham Rd., Toronto 12, Ont., Canada
Booker, C. A., Jr., 8001 Susquehanna St., Wilkinsburg 21, Pa.
Bremmer, L. F., 14269 24 Ave., S.W., Seattle 66, Wash.
Budd, W. E., 136–39 39 Ave., Flushing, L. I., N. Y.
Butenhoff, R. L., 132 Taylor Rd., Oak Ridge, Tenn.
Calvarese, J. F., Box 148, Valley Forge Rd., Wayne, Pa.
Canfora, A. E., 6501 17 Ave., Brooklyn 4, N. Y.
Cantor, T. E., 3015 Riverdale Ave., Riverdale 63, N. Y.
Caquelin, M. W., 123 17 St., N.E., Cedar Rapids, Iowa
Carter, W. R., 208–20 Cross Island Pkwy., Bayside, L. I., N. Y.
Casey, T. J., 5300 W. 84 St., Minneapolis 20, Minn.
Chambers, R. N., 182 Oakridge Ave., Summit, N. J.
Coffe, S. A., 1592 Carlyon Rd., E. Cleveland 12, Ohio
Coonley, K. E., 825 President St., Brooklyn, N. Y.
Cope, R. H., Jr., 23 S. Washington St., Port Washington, L. I., N. Y.
Cornet, J. F., 281 Grove St., Montclair, N. J.
Cottam, R. W., 68 Hillcrest Rd., Mount Vernon, N. Y.
Cotton, S., 72 Barker Ave., Eatontown, N. J.
Court, H. R., Jr., 159 Hoffman Ave., Elmont, N. Y.
Crawford, C. A., 1136 Milwaukee Ave., Chicago 22, Ill.
Cutler, M. L., 2412 Colston Dr., Silver Spring, Md.
Daniels, T., Prairie View A & M College, Prairie View, Tex.
Davis, D. P., 1408 Commonwealth Ave., West Newton 65, Mass.

(Continued on page 46A)

TIM ALEXANDER
Motorola Service Manager

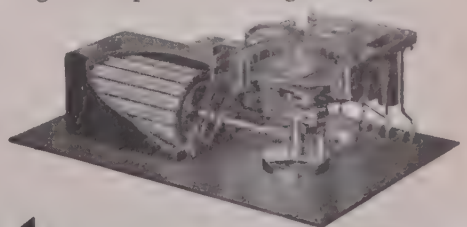
says: "Our Simpson Roto Ranger is used more than any other instrument in the shop"

Tim Alexander, supervisor of Motorola's Service Dept., is one of the nation's foremost experts in radio repair. His professional experience and know-how pays-off. It is no secret that part of this pay-off comes from using the finest testing equipment that money can buy.

Tim Alexander says, "Our Simpson Roto Ranger is used more than any other instrument in the shop and saves us time and money here at Motorola. It is efficient and the most fool proof high sensitivity A.C.–D.C. Volt–Ohm–Millimeter available anywhere near this price. The Roto Ranger's 18 automatic separate scales are large and easy to read. *They eliminate* errors because there is no confusion from numerous readings on one scale. This is a tremendous time and money saving improvement in a busy shop."

Take Mr. Alexander's Advice. To save your time, money, and eyesight—and to eliminate all possibility of errors, get a Simpson Roto Ranger today.

Write for Complete Descriptive Literature.



Simpson

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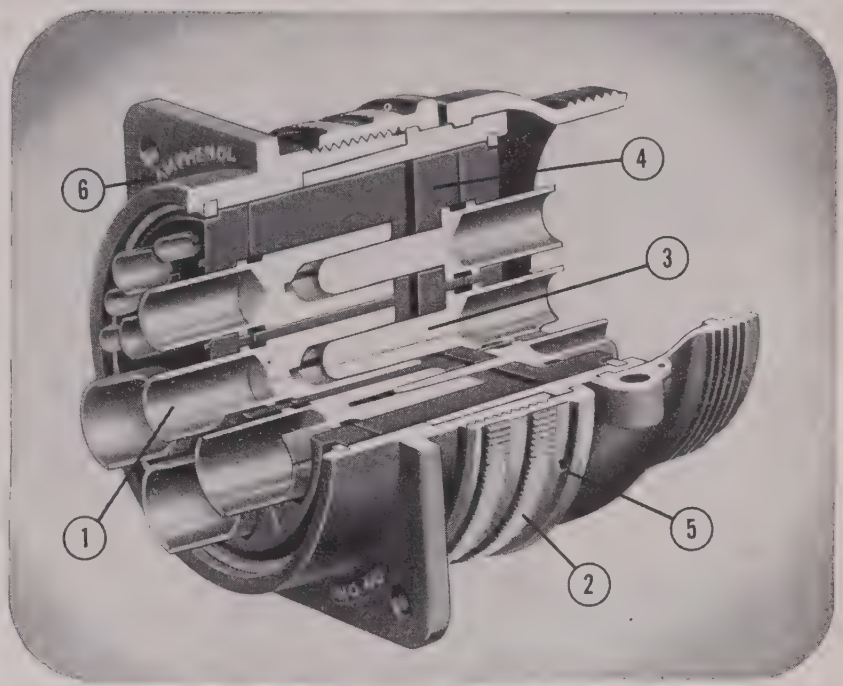

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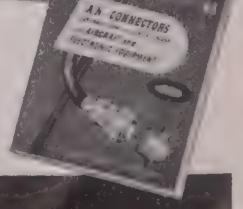

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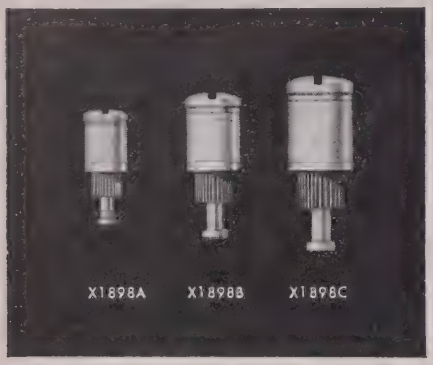

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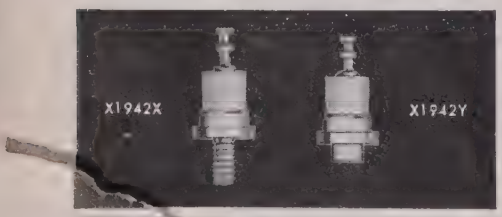

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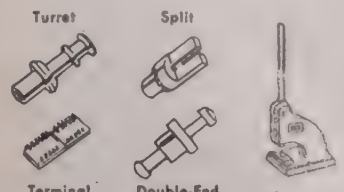

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Electronics research engineer experienced in electronics as well as engineering sciences and physics for research and de-

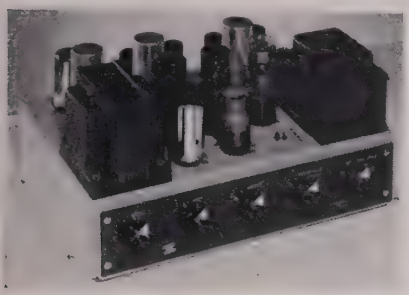
(Continued on page 51A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

All-Triode Amplifier

An all-triode laboratory amplifier and dynamic noise suppressor, type 211-A, is now available from the designer, **Hermon Hosmer Scott, Inc.**, 385 Putnam Ave., Cambridge 39, Mass.



The 211-A has a frequency range of 20 to 20,000 cps, and a peak power output of 14 watts. This rather high output from a triode amplifier, the manufacturer claims, is attained by a special stabilized grid-bias circuit.

Distortion is less than ½% at 5 watts, and 2% at 12 watts. Hum is approximately 80 db below maximum power output at normal volume. Triodes are used in all amplifying stages, and low-mu triodes are featured in the high-level stages.

Four-Frequency FM Monitor

A new monitor, the FMM-1, which measures carrier frequency, carrier intensity, and modulation index at a considerable distance from a fixed or mobile station, is now in production by **West Coast Electronics Co.**, 1601 S. Burlington Ave., Los Angeles 6, Calif.

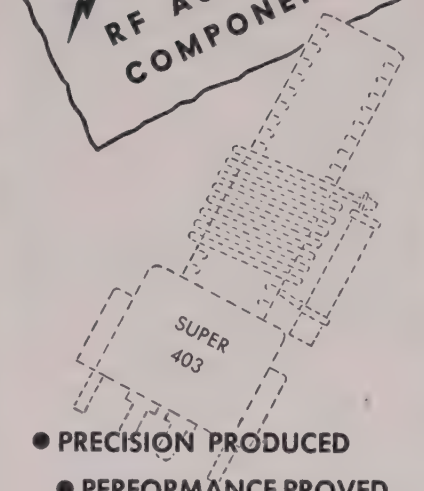
The specifications of the FMM-1 are: range, 30 to 20 Mc., any four frequencies within the band; rf input impedance, 52 ohms; a connector for RG-8/U coaxial cable is provided; rf sensitivity, 200 microvolts or better at all frequencies within the band; audio output, 500 milliwatts at 15 kc deviation; output impedance, 500 ohms; signal-to-noise ratio, 40 db at 200 microvolts input, 15 kc deviation at 400 cps; distortion is 2% or less; power supply, 105 to 125 volts, 50 to 60 cps.

Descriptive literature and price quotations available on request.

(Continued on page 58A)

NOTE THIS NAME

SUPER RF AUDIO TV COMPONENTS



● PRECISION PRODUCED

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SUPER ELECTRIC PRODUCTS CORP.

Pacing Electronic Progress With Ingenuity

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Announcing

The New Miniature

MULTIPOTS

For Extremely Fine Resistance Adjustments Where Space is Limited

★

SMALLEST TEN-TURN RHEOSTAT

Ever Produced

SERIES B
1" Dia. x 1" Length
Power Rating: 1½ Watts
Linearity: to within ±0.1%
Resistance: to 75,000 Ohms

★

OTHER MODELS

SERIES A: 1" Dia. x 2" Length
Power Rating: 3 Watts
Linearity: to within ±.05%
Resistance: up to 200,000 Ohms

STANDARD SERIES: 1½" Dia. x 2" Length
Power Rating: 5 Watts
Linearity: to within ±.05%
Resistance: up to 350,000 Ohms

All MULTIPOTS unconditionally guaranteed. Write for data sheets to:

FORD ENGINEERING CO.

Box 153 Los Angeles 41, Calif.

PANORAMIC

Ultrasonic Analyzer

Model SB-7

for Easy, Fast Ultrasonic Spectrum Analysis

An entirely new instrument, the SB-7 provides continuous, high speed graphic displays of frequency versus amplitude of signals between 2KC and 300KC. Allows observation of many signals at one time. Enables instant identification of signals and their characteristics. Provides rapid indications of random changes in energy distribution. Direct Reading.

SPECIFICATIONS

Frequency Range: 2KC-300KC, stabilized linear scale

Scanning Width: Continuously variable from 200KC to zero.

Four Input Voltage Ranges: 0.05V to 50V. Full scale readings obtainable with 1MV to 50V.

Amplitude Scale: Linear and two decade log

Amplitude Accuracy: Within 1db. Residual harmonics suppressed by at least 50db.

Resolution: Continuously variable. 2KC at maximum scanning width, 500c.p.s. for scanning widths below 8KC.

Input Impedance: 1 megohm shunted by 25 mmf, approximately constant.

USES

- Harmonic and Cross Modulation Studies
- Filter and Transmission Line Checks
- Vibration Analysis
- Noise Studies
- Telemetering
- Monitoring

Write for Complete Information

PANORAMIC RADIO CORP

10 So. Second Ave. Mount Vernon, N. Y.

Exclusive Canadian Representative: Canadian Marconi Company

An authoritative book by two experts on

PHOTOELECTRICITY and its APPLICATION

By V. K. ZWORYKIN, Director of Electronic Research, Vice-President and Technical Consultant, Radio Corporation of America, and

E. G. RAMBERG, Research Physicist, R.C.A. Laboratories

This new volume, a successor to Zworykin's and Wilson's *Photocells and Their Applications*, is intended to familiarize the reader with the properties, preparation, and use of photoelectric devices.

Covers Subject Fully

The book gives an integrated representation of the whole field of photoelectricity, covering fundamental principles, methods of preparation, photocell circuits, and the various principal fields of application of photoelectric devices. The authors fully discuss phototubes, photoconductive cells, barrier-layer cells, and other photoelectric devices with respect to basic mechanism, preparation, utilization, and applications.

Designed for Practicality

The tone of the book is primarily practical. Its principles can easily be adapted for application to everyday problems encountered in the field and the laboratory. Mathematical developments are restricted to footnotes, and MKS units are used throughout. The book contains many illustrations which demonstrate present-day applications of photoelectricity in television, sound film, facsimile, infra-red signalling and in other fields.

April 1949 494 pages 393 illus. $7.50

10-Day Examination Offer

ON APPROVAL COUPON

JOHN WILEY & SONS, INC.
440 Fourth Ave., New York 16, N.Y.

Please send me, on 10 days' approval, a copy of Zworykin and Ramberg's PHOTOELECTRICITY AND ITS APPLICATION. If I decide to keep the book, I will remit $7.50 plus postage; otherwise, I will return the book postpaid.

Name .....
Address .....
City ..... Zone .... State .....
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(Offer not valid outside U.S.) IRE-5-49

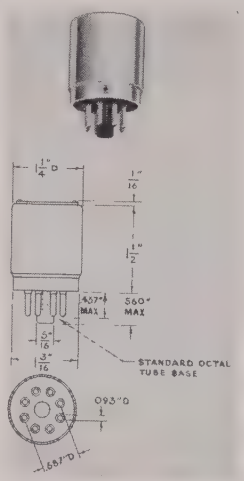
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 57A)

Crystal-Temperature Stabilizer

A new crystal-temperature stabilizer, type TCO-1, which is a miniature crystal oven engineered for modern military and commercial communications equipment, by **Bliley Electric Co.**, 227 Union Station Bldg., Erie, Pa.



This oven is designed for use with Bliley type BH6 crystal units which mount in an internal socket. This combination will provide frequency stability down to $\pm 0.0001\%$ while crystal temperature is maintained within $\pm 2°C$.

The standard unit is supplied for operation at $75°C \pm 2°C$ and is equipped with a 6.3-volt heater rated at 5.5 watts. Supplied with type BH6 crystal units at any specified frequency in range 1 to 100 Mc, the TCO-1 oven introduces a new form factor in temperature-stabilized crystals for high precision.

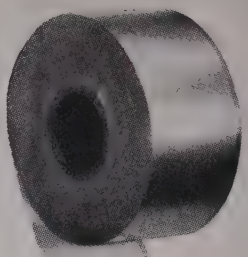
Recent Catalogs

• • •Two bulletins: the first explaining the procedure of converting a four-terminal to a five- or six-terminal meter socket, the second, a 4-page catalog illustrating the basic line of No. 9000 electric meter sockets, with complete specifications, by **Anchor Mfg. Co.**, 30 Huntington Ave., Boston 16, Mass.

• • •A new brochure describing the complete line of products, especially the wide variety of oscilloscopes manufactured by **Furzehill Labs., Ltd.**, Boreham Wood, Herts., England. Contact should be made through **American British Technology, Inc.**, 57 Park Ave., New York 16, N. Y.

• • •A general catalog, the first to be released in some time, and therefore including a number of new items not previously mentioned, by **Meissner Mfg. Div., Maguire Industries, Inc.**, Mt. Carmel, Ill.

(Continued on page 60A)



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When you use Metallized Condenser Paper, it is possible to:

1. Manufacture a one-layer condenser.
2. Save 75% space.
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4. Use less impregnating materials.
5. Eliminate the use of foil electrodes.
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Get all the facts on Smith Metallized Condenser Paper as it applies to *your* industry. A card, letter or phone call to Smith Paper, Inc., Lee, Massachusetts (telephone Lee 7) will bring you the information you seek, without obligation on your part.

Manufacturers of Condenser Papers

SMITH PAPER, INC.
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SMITH

Cramer

TYPE TEC
TIME
DELAY
RELAY

FUNCTION

Cramer TEC Time Delay Relays provide an adjustable or fixed time delay between the closing and opening of a load circuit. Automatic reset feature restores timer to normal start position when control circuit fails or is de-energized. Also available with reverse clutch that prevents reset in case of power failure.

CONSTRUCTION

Consist of a self-starting, slow speed synchronous motor with sturdy gear train . . . an electro-magnetically operated clutch . . . a switch and switch-tripping mechanism. Complete mechanism mounted on die-cast front plate with dust protected enclosure. Dials and cases conform to standard instrument panel specifications for either flush or surface mountings. Dials equipped with progress indicators, convenient thumbscrew setting.

TIME RANGES

Time Range	Dial Divisions	Minimum Setting	Type No.
15 sec.	.25 sec.	.75 sec.	TEC-15S
30 sec.	.5 sec.	1.5 sec.	TEC-30S
60 sec.	1 sec.	3 sec.	TEC-60S
2 min.	2 sec.	6 sec.	TEC- 2M
5 min.	5 sec.	15 sec.	TEC- 5M
15 min.	15 sec.	45 sec.	TEC-15M
30 min.	30 sec.	90 sec.	TEC-30M
60 min.	1 min.	3 min.	TEC-60M
3 hrs.	5 min.	15 min.	TEC- 3H
6 hrs.	10 min.	30 min.	TEC- 6H

Standard time ranges for Cramer Type TEC and TER Time Delay Relays are shown above. If your special requirement suggests variations from standard specifications, write us. For full technical description of all Cramer Time Delay Relays, send for bulletins 700C, 800E and 900D.

THE R. W. CRAMER COMPANY, INC.
Box #12, Centerbrook, Conn.

INTERVAL – CYCLE – IMPULSE – PERCENTAGE TIMERS
RUNNING TIME METERS – GEARED SYNCHRONOUS MOTORS

4CR49

NEW... Improved Wiring Eliminates Leakage

TYPE 12AT & TYPE 12ATK (KIT)

TRANSMISSION MEASURING SET

Range: 111 db. in 0.2 steps.
Frequency resp.: 0.1 db. from 0 to 20 kc.
Accuracy: 0.1 db.
Impedance, load section: 4, 8, 16, 50, 150, 200, 500, & 600 ohms.
Impedance, transm. set.: 50, 150, 200, 500 & 600 ohms.
Reference level: 1mw. into 600 ohms.
Circuit: "T", unbalanced.
Attenuators: 10x10, 10x1 & 5x0.2 db.
Load carr. cap.: Transm. sect. 1 w. Load section 10 w.

A precision Gain Set with specially developed wiring that permits no troublesome leakage and provides improved frequency characteristics. Available completely assembled, or in kit form—which permits the sale of a high accuracy instrument at a low price.

WRITE FOR DESCRIPTIVE BULLETIN

TECH LABORATORIES, INC.
Manufacturers of Precision Electrical Resistance Instruments
PALISADES PARK, NEW JERSEY

S·S·White MOLDED RESISTORS

The "All-Weather" Resistors

ARE USED IN THIS HIGH-SPEED GEIGER-MULLER COUNTER

They're used in the quenching circuit. El-Tronics, Inc., Philadelphia, Pa. the manufacturer says—"We have been using and will continue to use S.S.White Resistors since we find them extremely satisfactory and most compact of all types available."

Photo courtesy of El-Tronics, Inc. Philadelphia, Pa.

S.S.WHITE RESISTORS

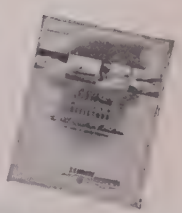
are of particular interest to all who need resistors with inherent **low noise level** and **good stability** in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS

STANDARD RANGE
1000 OHMS TO
9 MEGOHMS

WRITE FOR BULLETIN 4505

It will give you full details about S.S.White Resistors including construction, characteristics, dimensions, etc. A copy, with Price List, will be mailed at your request.



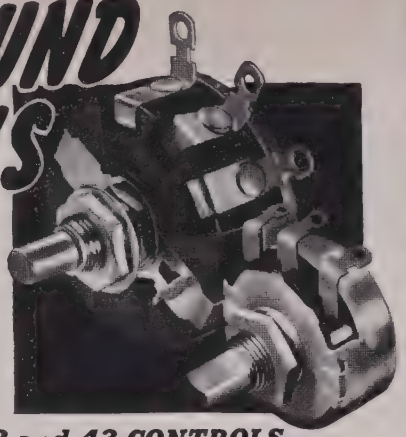
S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. — DEPT. GR, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AND ACCESSORIES
MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

One of America's AAAA Industrial Enterprises

WIRE-WOUND CONTROLS



★ Winding skill second to none
★ Large and small controls
★ Velvety-smooth rotation, always
★ Minimized wear-and-tear
★ Taps and tapers. Tandem units

CLAROSTAT SERIES 58 and 43 CONTROLS

The large-sized Series 58 Clarostat rheostat or potentiometer offers laboratory-grade performance at mass-production cost. 1-21/32" dia. 1 to 100,000 ohms. 3 watts, linear. The finest standard wire-wound control made!

The midget Series 43 control is a real space-saver. Only 1⅛" dia. 1 to 10,000 ohms. 2 watts, average.

Hundreds of thousands of Clarostat wire-wound controls are in daily use. Their performance, dependability and long life, are a matter of record.

1949 IS TV YEAR

Ask for Bulletins 116 and 118. Let us quote on your needs.

CLAROSTAT

Controls and Resistors

CLAROSTAT MFG. CO., INC. • DOVER, NEW HAMPSHIRE • *In Canada:* CANADIAN MARCONI CO., LTD. *Montreal, P.Q., and branches*

Desirable Select Unused Surplus Items

Link Radio Transmitter-Receivers Type 50 UFS	Price on Request
Radar Type SF, complete with all components	$1,480.00
R5/ARN-7 Radio Compasses, *complete*	125.00
BD-72 Field Telephone Switchboards	37.50
BC-375-E's, complete new with all tuning units, dynamotor, tubes, plugs, etc.	97.50
TDE Radio Transmitters	675.00
Type SCR-522's—(Slightly Used)	65.00
Collins TCS's Navy units	575.00
Hallicrafters Radios, Model No. S-40, 110/240 Volts AC, 50/60 Cycle—Universal	87.50
Telegraph Transmitters—Model ET-8023 D1	425.00
Generator Lighting Plants—Type PE197, 5KW, 120 Volt AC, 50/60 Cycle, Single Phase	675.00
Generator Gasoline Engine Driven Lighting Plants Type 5KW, 110 Volt AC, 50/60 Cycle, Single Phase	550.00
Reading Storage Batteries, 185 amp-hours, 6 volts	7.50
Exide Storage Batteries, 150 amp-hours, 12 volts	17.50
Prism Binoculars—Zeiss Type—Regular Optics 30 per case	44.00*
Prism Binoculars—Zeiss Type—Coated Optics 20 per case	54.00*

TUBES

Type 10Y	$ .55	Type 805	3.80
211	.85	807	1.14
250TH	21.30	808	2.80
304TL	1.10	810	5.50
450TH	22.75	836	.95
450TL	36.50	861	27.50
803	4.50		

* Plus 20% Federal Excise Tax. Subject to prior sale.

FRENCH-VAN BREEMS, INC.
405 Lexington Avenue, New York 17, N.Y.
Oregon 9-3650

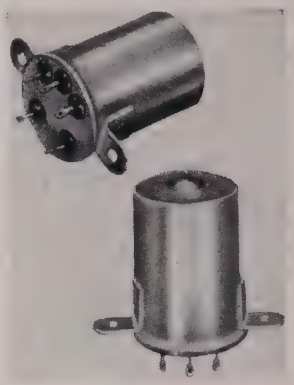
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 58A)

Hermetically Sealed DC Relay for High-Altitude Requirements

A hermetically sealed dc miniature relay, type CX3554, has been developed by **Struthers-Dunn, Inc.**, 150 N. 13 St., Philadelphia 7, Pa., to meet the extreme operating conditions of modern high-altitude and jet-propelled aircraft.



Special aviation design features include shock resistance up to 50 G's; vibration resistance better than 10 G's; high-speed opening and closing without contact bounce; and reliable operation over an ambient temperature range of −75°C to +200°C. A high degree of hermetic sealing makes the unit insensitive to humidity changes and capable of rated operation at altitudes as high as 70,000 feet.

The relay has SPDT contacts nominally rated at 2 amperes and capable of withstanding inrushes of 12 amperes at 26.5 volts dc. The coil is rated at 26.5 volts dc with an operating range of 18/32 volts dc. Of cylindrical shape with mounting "feet," the relay is approximately $1\frac{3}{4}$" high including terminals, with a flange diameter of 1.040", and $1\frac{3}{8}$" between mounting hole centers. Complete details will gladly be sent upon request to the manufacturer

Recent Catalogs

• • • A bulletin on "Socket and Mounting Notes for Raytheon Flat Press Subminiature Tubes," which also explains other methods of connecting to the tube, shielding it, and potting it in plastic, by **Raytheon Mfg. Co., Inc.**, 55 Chapel St., Newton 58, Mass.

• • • A new television components folder No. P-1, illustrated with photographs and schematic diagrams, in which 19 television parts are analyzed according to function, general use considerations, ratings, and connections, by **Transvision, Inc.**, 460 North Ave., New Rochelle, N. Y.

G-E BEAM POWER TRANSMITTING TUBES

GL-2E26

—always ready for dependable service—minutes or hours of it!

—need low drive, so ask less of your power supply.

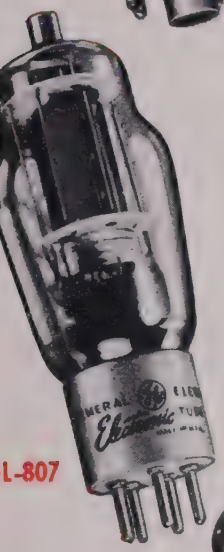
—replacements are convenient to obtain...you can secure new tubes fast from your local G-E tube distributor!

DESIGNERS of equipment give first place to General Electric beam power *economy* tubes. Their low drive requirements — a characteristic of this type — pay off in less space needed for the driving stages of a transmitter. That's Saving No. 1! And drain on the battery or other source of power supply is reduced . . . Saving No. 2.

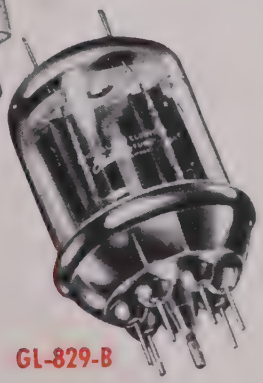
If you operate police, taxicab, or ambulance radio equipment — if you maintain an airport, ship-to-shore, or other communications system — the benefits of a more compact transmitter and lower power consumption are matched by G-E tube dependability. These beam power types are amply proved in tough service!

A complete line of General Electric tubes is available, spanning the range of outputs and frequencies in communications work. Designers and builders of equipment, through their nearby G-E electronics office, may call on experienced G-E tube engineers to help select the right types for new circuits.

Transmitter owners will find that same-day, often same-hour service is given by their local G-E distributor on tube replacements. From coast to coast, stocks are in readiness for *your* emergency call! Get to know your G-E tube distributor; he's equipped to serve you fast . . . and well! *General Electric Company, Electronics Department, Schenectady 5, New York.*



GL-807



GL-829-B

GL-813

Ratings (ICAS) for typical operation, Class C plate-modulated

Type	Plate voltage	Plate current	Driving power (approx)	Power output (approx)	Freq. at max ratings
GL-2E26	500 v	54 ma	0.15 w	18 w	125 mc
GL-807	600 v	100 ma	0.4 w	42.5 w	60 mc
GL-829-B	600 v	150 ma	0.9 w	70 w	200 mc
GL-813	2,000 v	200 ma	4.3 w	300 w	30 mc

Photo by courtesy N. Y. State Police

GENERAL ELECTRIC

180-H4

FIRST AND GREATEST NAME IN ELECTRONICS

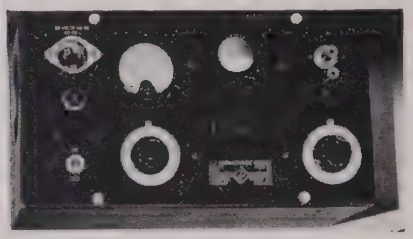
NEWS—NEW PRODUCTS

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 18A)

RF Capacitance Meter

A new type 1612-A rf capacitance meter designed to rapidly measure and test small capacitors (up to 1,200 $\mu\mu$f.) is now in production at **General Radio Co.**, 275 Massachusetts Ave., Cambridge 39, Mass.



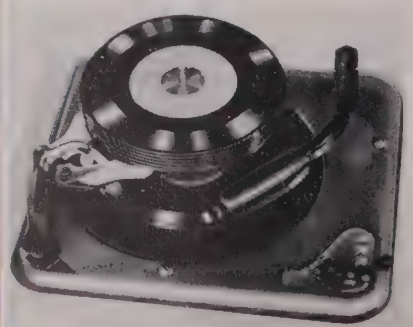
Measurement is made by a substitution method in which the capacitance of a calibrated air capacitor is reduced to reestablish resonance after an unknown capacitor is connected. Resonance is indicated by maximum deflection of a meter. Two ranges are provided, 0 to 80 $\mu\mu$f and 0 to 1,200 $\mu\mu$f, and range switching is accomplished automatically as the dial is rotated. Measurements are made at a frequency of 1 Mc.

Maximum meter deflection can also be used as an indication of loss, and hence as a basis for rejection of high-loss capacitors when compared to a standard sample.

The meter operates from a 115-volt source, ac or dc. Dimensions are: $12'' \times 6\frac{5}{8}'' \times 7\frac{1}{2}''$, weight 11 lbs.

Three Speed, all Size Record Changer

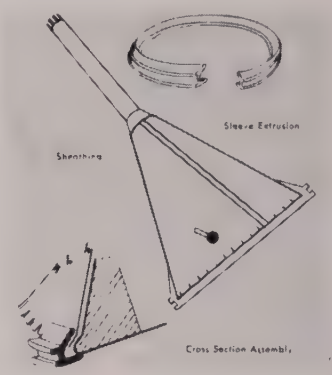
As a solution to the recent addition of two new-type records to be played at different speeds, **General Instrument Corp.**, 829 Newark Ave., Elizabeth, N. J., offers a changer designed to automatically play 10 or 12" 78 rpm, 7, 10, and 12" $33\frac{1}{3}$ rpm, and the new 45 rpm records with the same pickup arm.



The new changer has a conventional spindle diameter, and the problem of the large hole diameter of the 45-rpm record is overcome by the use of plastic adaptor buttons. These buttons are inserted in the center of the 45 rpm records, reducing the hole diameter to the size of the standard spindle.

Plastic Insulation for Metal TV Tubes

A new mounting and insulating sleeve constructed of a polyethylene compound, "Aeroflex," which also guards the tube against shock and vibration in shipping is being marketed by **Anchor Plastics Co.**, 533 Canal St., New York 13, N. Y.



This sleeve fits over the tube cone and is held in place by an extruded mounting ring; thus all metal portions of the tube are covered, eliminating accidental contact.

"Aeroflex" has been adapted to this new use through the development of a process in the extrusion of thermoplastics. The compound is extruded in circular shapes, eliminating the difficulty in bending.

Recent Catalogs

• • • A new bimonthly exterior house organ, devoted to the latest developments in the connector and electrical specialty fields, will be sent on request to those writing to the Editor, *Cannonade*, **Cannon Electric Dev. Co.**, 3209 Humboldt St., Los Angeles 31, Calif.

• • • A data folder on capacitors with necessary information concerning design, capacitance, containers, chassis layouts, and mountings and sockets by **P. R. Mallory & Co., Inc.**, 3029 E. Washington St., Indianapolis 6, Ind., is available on request.

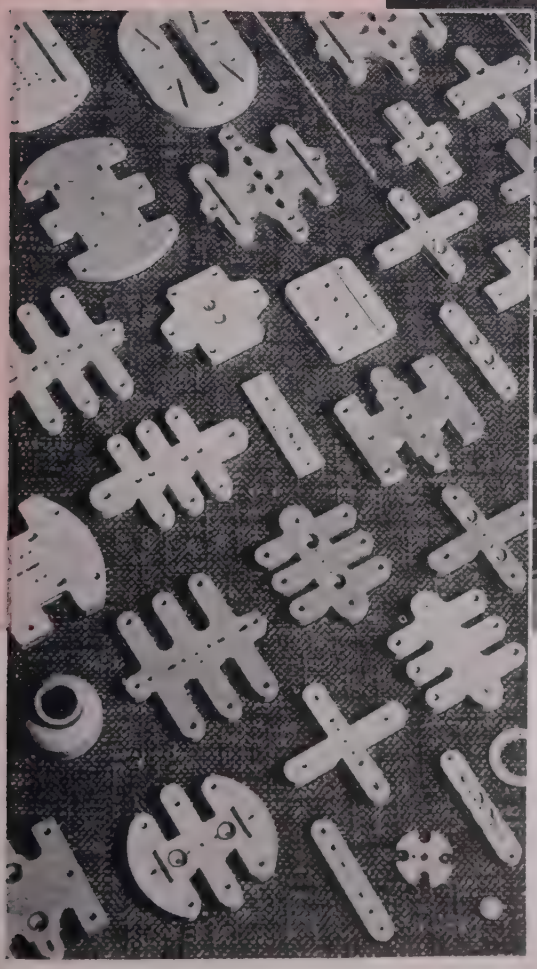
• • • A 28 page illustrated catalog, CDM-2A, describing stocked permanent magnets has been issued by **General Electric Co., Chemical Dept.**, Pittsfield, Mass. A wide variety of cast and sintered alinco magnets, as well as special magnetic alloys, are listed.

• • • The March issue of *CEC Recordings* has an interesting article concerning a new sampling probe that raises leak detector sensitivity 1,000 times. This may be secured by writing to **Consolidated Engineering Corp.**, 620 N. Lake Ave., Pasadena 4, Calif.

(Continued on page 45A)

die pressed

Die pressing enables AlSiMag to produce many shapes and sizes in large quantity . . . speedily, and at low cost



One of several batteries of AlSiMag presses. These presses range from fully automatic high speed presses to large presses handling pieces up to 14" square.

For better, speedier service, AlSiMag makes its dies in its own modern die shop. This die shop serves only our customers, operates on a non-profit basis. Superior die pressing equipment and technique is another reason why American Lava Corporation is known as Headquarters for Custom Made Technical Ceramics.

AlSiMag

AMERICAN LAVA CORPORATION

48TH YEAR OF CERAMIC LEADERSHIP

CHATTANOOGA 5, TENNESSEE

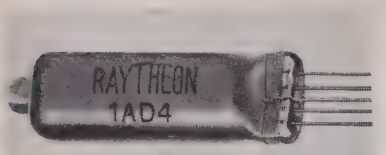
SALES OFFICES: ST. LOUIS, MO., 1123 Washington Ave., Tel: Garfield 4959 • NEWARK, N. J., 671 Broad St., Tel: Mitchell 2-8159 • CAMBRIDGE, Mass., 38 B Brattle St., Tel: Kirkland 4498 • CHICAGO, 9 S. Clinton St., Tel: Central 1721 • LOS ANGELES, 324 N. San Pedro St., Tel: Mutual 9079 • PHILADELPHIA, 1649 N. Broad St.

NEWS and NEW PRODUCTS

JUNE, 1949

Subminiature Filamentary Pentode

The **Raytheon Mfg. Co.,** 55 Chapel St., Newton 55, Mass., claims that, for the first time, a filamentary pentode is available with performance equivalent to that of many heater-cathode types. The type

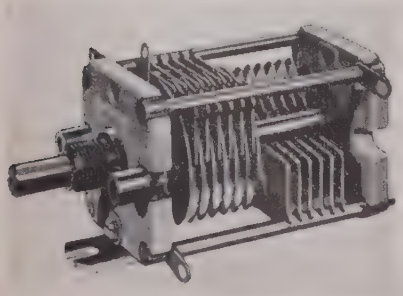


1AD4 is a new subminiature sharp-cutoff pentode, shielded for rf applications, with a nominal mutual conductance rating of 2000 micromhos and an average plate current of 3 milliamperes, with 45 volts plate and screen supply. The filament rating is 1.25 volts, 100 ma.

This new type, which was originally developed for the Thermionics Branch of the Evans Signal Laboratory, is now available commercially from Raytheon.

Non Fluctuating Variable Capacitor

A new line, 167, of variable capacitors, which, the manufacturer claims, are free of fluctuation in capacity, even under the most severe operating conditions, has been engineered by **E. F. Johnson Co.,** Waseca, Minn.



This new line of variables possesses new and perfected ceramic soldering. The ceramic band is stronger than the steatile end plates themselves. There are no eyelets, nuts or screws to work loose, causing stator wobble and capacity fluctuations. Stator terminals, mounting posts and rotor bearings are all ceramic soldered. Efficient operation is obtainable on frequencies as high as 500 megacycles.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

New Type Wow Meter

A flutter, wow, and drift percentage analyzer, model 491, type A—the first such instrument, the manufacturer claims, with a built-in high-gain amplifier and limiter—is in production by **Amplifier Corp. of America,** 398-1 Broadway, New York, N. Y.

Three distinct and simultaneous readings may be made of flutter, wow, and drift. Hum, noise, switching surges, and other extraneous transients have no effect on the reading or stability of the instrument.

Three scales: 0.3%, 1.0%, and 3.0%, are calibrated for flutter, wow, and drift readings. Variable capacitive and resistive elements enable accurate calibration and flutter measurements to be made on all recording and playback equipment whose normal linear rotational speed falls within ±5% of standard.

Transformer for Reluctance Cartridges

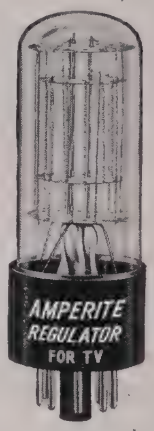
The Acrosound T1-100, a transformer to preamplify and equalize the output of reluctance-type pickup cartridges, is the first of a line of components to be put on the market by **Acro Products Co.,** 5328 Baltimore Ave., Philadelphia 43, Pa.

The unit is used to replace the usual tube preamplifier and equalizer, and, the manufacturer claims, does so with the elimination of hum, distortion and instability usually associated with preamplifiers.

New design principles that have been applied in the design of the T1-100 provide full undistorted high-frequency response, plus a rising bass characteristic for low-frequency equalization. The output of the transformer provides sufficient voltage to energize the tuner, phonograph, or other medium-level high-impedance input channels.

Television Ballast Tube

A new television ballast tube which is hermetically sealed and filled with helium, producing rapid cooling, has been placed on the market by **Amperite Co., Inc.,** 561 Broadway, New York 12, N. Y.



The tube is produced with as many as five separate controlling elements. Furthermore, to withstand the possible overload in television receivers, some of the 2.5-watt elements are designed to withstand 40 watts, an overload of 2,000%. Voltage breakdown between elements is 13,000 volts dc.

Diameter of the tube is $1\frac{1}{4}''$, seated height is $3''$

Recent Catalogs

• • • A new bulletin, F-2, entitled "How to Select Flexible Waveguide Assemblies," shows three distinct types of flexible waveguide constructions and their uses, applications, and characteristics. Of special interest is a discussion of rigid-flexible combination assemblies showing the attachment of flexible to rigid waveguides with the use of flanges, by **Technicraft Laboratories, Inc.,** Thomaston & Waterbury Rds., Thomaston, Conn.

• • • A new, detailed information catalog concerning the greatly expanded line of capacitors developed to serve the entire field can be secured from the **Illinois Condenser Co.,** 1616 N. Throop St., Chicago 22, Ill.

• • • A bulletin describing the type 110 Slide-Wire Resistance Boxes, designed as a laboratory substitute for the more expensive decade resistance boxes, is available to those interested from **Technology Instrument Corp.,** 1058 Main St., Waltham 54, Mass.

• • • A booklet stating reasons for galvanic cell corrosion, as well as methods for helping to overcome it (complete in all engineering details including drawings and other essential illustrative material), may be obtained from **International Nickel Co., Inc.,** New York 5, N. Y.

(Continued on page 26A)

New washing machine cuts TV tube costs... with the help of Inco Alloys

THE SALVAGING of defectively coated television tube envelopes has been a problem . . . with an important bearing on final costs.

Tube coatings are burned on at 450°C. The method of removing coatings, at present, is to etch them off with ammonium bifluoride or hydrofluoric acid.

Attempts to mechanize the "washing" or etching process ran into this difficulty . . . most metals suitable for machine construction were unable to withstand the corrosive attacks of the etchant solutions.

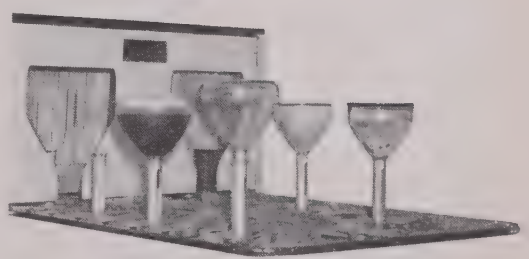
Inco's Corrosion Engineering Section helps

Now the Better Built Machinery Co. of New York City has designed a production machine to clean out new tube envelopes and also salvage defective ones. The problem of a material to resist action of the violently corrosive etching fluids was referred to International Nickel, where corrosion problems have been analyzed for over 40 years. Inco's Corrosion Engineering Section recommended: *Monel** for spray chamber liners and tube holders; Ni-Resist* #2 castings for conveyors.

Result? The new Better Built tube washing machine . . . first of its kind . . . is now at work in the Allan B. Dumont Laboratories. And with tube envelope cleaning and reclaiming on a production basis, tube costs are expected to be significantly lowered.

If you have metal problems, talk them over with Inco. One of the versatile Inco Nickel Alloys may be the solution you are seeking.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.



How the Better Built Tube Washer Operates

New tube envelopes and those with defective coatings are loaded onto the Monel tube holders. A conveyor, made of Ni-Resist #2 castings, carries the tubes through a Monel-lined spray chamber where etchant solutions "wash" away the unwanted coatings.

Final cleaning of the tubes is accomplishd with a hot caustic wash, followed by several pre-rinses and a final rinse in distilled water.

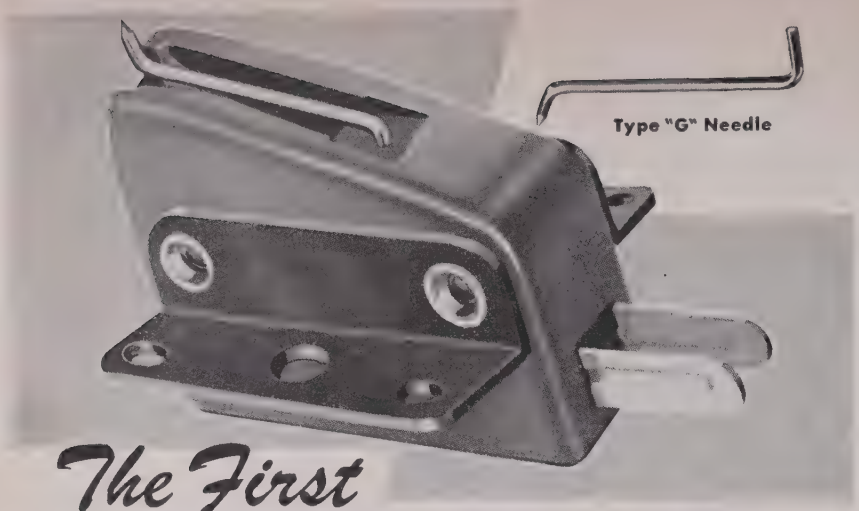
The washing machine is 30 ft. long, 4½ ft. wide, and 6 ft. high. It follows the general design of standard Better Built machines used for washing glass containers and laboratory ware.

For further information about Better Built machines, write directly to:

BETTER BUILT MACHINE COMPANY
73 East 130th St., New York, N. Y.

EMBLEM OF SERVICE
NICKEL INCO ALLOYS

MONEL* • "K"* MONEL • "R"* MONEL • "KR"* MONEL
NICKEL • "D"* NICKEL • "Z"* NICKEL • INCONEL*
*Reg. U. S. Pat. Off.



The First
CERAMIC CARTRIDGE
with
CHANGEABLE NEEDLE
LIGHT WEIGHT
LOW PRESSURE

HERE'S THE FIRST major engineering stride in phonograph pickup cartridges employing ceramic elements since Astatic first pioneered in this type unit last year. It's Astatic's tiny new gem — the "GC" — the first cartridge of its kind with replaceable needle. Takes the special new Astatic "Type G" needle — with either one or three-mil tip radius, precious metal or sapphire — which slips from its rubber chuck with a quarter turn sideways. Resistance of the ceramic element to high temperatures and humidity is not the only additional advantage of this new development. Output has been increased over that of any ceramic cartridge previously available. Its light weight and low minimum needle pressure make it ideal for a great variety of modern applications. Details of performance appear in the accompanying table.

Model	Cartridge Type	Minimum Needle Pressure	Output Voltage	Frequency Range (c.p.s.)	Needle Type	Application
GC	Ceramic	6 gr.	0.5*	50-10,000	G (1 mil tip radius)	33-1/3 and 45 RPM Records
GC-78	Ceramic	12 gr.	0.65†	50-10,000	G-78 (3 mil tip radius)	Standard 78 RPM Records

*Columbia #281 Test Record †Audio-tone Test Record

Write for additional information

THE Astatic CORPORATION
ASTATIC CONNEAUT, OHIO
IN CANADA: CANADIAN ASTATIC LTD. TORONTO, ONTARIO

SECTION MEETINGS

BALTIMORE

"Development of a Large Metal Kinescope for Television," by H. P. Steier, Radio Corporation of America; March 22, 1949.

BUFFALO-NIAGARA

"Electrical Problems in Stratovision," by A. A. Nimms, Westinghouse Electric Company; February 17, 1949.

"Some Recent Developments and Applications of Germanium Crystals," by S. T. Martin, Sylvania Electric Products Company; March 16, 1949.

CEDAR RAPIDS

"Some Aspects of Annular Circuits," by D. Priest, Eitel-McCullough, Inc.; March 15, 1949.

"Current Problems in Frequency Allocation," by G. F. Leydorf, Radio Station WJR; April 13, 1949.

CINCINNATI

"New Seeds for the Fields of Engineering," by G. Wenot, Science Illustrated; March 23, 1949.

COLUMBUS

"Recent Developments in Sound Recording," by T. Lynch, Electronic Engineering Brush Development Company; February 9, 1949.

"Television Demonstration," by J. A. Hatchwell, Engineering RCA Service Organization; March 23, 1949.

CONNECTICUT VALLEY

"The Radio Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; March 24, 1949.

DALLAS-FORT WORTH

"High Frequency — Applications in Aircraft, by D. T. Doherty, Student, Southern Methodist University; March 21, 1949.

"Electrical Techniques in Geophysics," by J. W. Roby, Student, Southern Methodist University; March 21, 1949.

"Amplifying the Brain Waves," by H. J. Spurlock, Student, Southern Methodist University; March 21, 1949.

"A Photoelectric Brightness Meter," by J. Fleck, Student, Southern Methodist University; March 21, 1949.

DAYTON

"Related Frontier Problems in Electronics and Aerodynamics," by S. Ramo, Hughes Aircraft Company; April 14, 1949.

DENVER

"Geiger Counters and Uranium Exploration," by P. M. Lahue, Consulting Engineer; April 8, 1949.

DES MOINES-AMES

"Television Networks—Coaxial and Microwave," by F. E. Baird, Northwestern Bell Telephone Company; March 16, 1949.

"A Report on the Annual Convention," by C. F. Quentin, Cowles Broadcasting Company; March 16, 1949.

Election of Officers; March 16, 1949.

DETROIT

"Engineering Aspects of the Transistor," by J. A. Morton, Bell Telephone Laboratories; March 22, 1949.

FORT WAYNE

"The Development and Application of Railroad Communication," by A. A. Curry, Farnsworth Television and Radio Company; March 28, 1949.

(Continued on page 36A)

10 CENTIMETER

WAVEGUIDE DIRECTIONAL COUPLER, 27 db. Navy type CABV-47AAN, with 4 in. slotted section as shown $42.50
SQ. FLANGE to rd choke adapter, 18 in. long OA 1½ in. x 3 in. guide, type "N" output and sampling probe $32.00
"S" BAND CRYSTAL MOUNT, gold plated, with 2 type "N" connectors $12.50
PICKUP LOOP, Type "N" Output $2.75
TR BOX Pick-up Loop $1.25
POWER SPLITTER: 726 Klystron input, dual "N" output $5.00
MAGNETRON TO WAVEGUIDE coupler with 731-A duplexer cavity, gold plated $27.50
10 CM WAVEGUIDE SWITCHING UNIT, switches 1 input to any of 3 outputs. Standard 1½" x 3" guide with square flanges. Complete with 115 vac or dc arranged switching motor. Mfg. Raytheon, CRP 24AAS. New and complete $150.00
10 CM END-FIRE ARRAY POLYRODS ....$1.75 ea.
"S" BAND Mixer Assembly, with crystal mount, pick up loop, tunable output $3.00
721-A TR CAVITY WITH TUBE. Complete with tuning plungers $12.50
10 CM. McNALLY CAVITY Type SG $3.50
WAVEGUIDE SECTION, MC 445A, rt. angle bend, 5½" ft. OA. 8" slotted section $21.00
10 CM OSC. PICKUP LOOP, with male Homedell output $2.00
10 CM DIPOLE WITH REFLECTOR in lucite ball, with type "N" or Sperry fitting $4.50
10 CM FEEDBACK DIPOLE ANTENNA, in lucite ball, for use with parabola ⅞" Rigid Coax Input $8.00

⅞" RIGID COAX—⅜" I.C.

RIGHT ANGLE BEND, with flexible coax output pick-up loop $8.00
SHORT RIGHT ANGLE bend, with pressurizing nipple $3.00
RIGID COAX to flex coax connector $3.50
STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $5.00
RT. ANGLES for above $2.50
RT. ANGLE BEND 15" L. OA $3.50
FLEXIGLE SECTION, 15" L. Male to female $4.25
MAGNETRON COUPLING to ⅞" rigid coax, with TR pickup loop, gold plated $7.50
ROTATING JOINT—P O SCR584 .....$35.00
DIPOLE ASSY—P O SCR584 .....$25.00
FLEX COAX SECT. Approx 30 ft. $16.50

⅞" RIGID COAX—¼" I.C.

⅞ RIGID COAX. Bead Supported $1.20
SHORT RIGHT ANGLE BEND $2.50
Rotating joint, with deck mounting $15.00
RIGID COAX slotted section CU-60/AP $5.00

MICROWAVE ANTENNAS

APS-15 Antennas. New $99.50
AN MPG-1 Antenna. Rotory feed type high speed scanner antenna assembly, including horn parabolic reflector. Less internal mechanisms, 10 deg. sector scan. Approx. 12'L" x 4'W x 3'H. Unused. (Gov't Cost—$4500.00) $250.00
APS-4 3 cm. antenna. Complete. 14½ dish. Cutler feed dipole directional coupler, all standard 1" x ½" waveguide. Drive motor and gear mechanisms for horizontal and vetical scan. New, complete ..$65.00
AN/TPS3. Parabolic dish type reflector approx. 10' diam. Extremely lightweight construction. New, in 3 carrying cases $89.50
RELAY SYSTEM PARABOLIC REFLECTORS: approx. range: 2000 to 6000 mc. Dimensions: 4¼' x 3' rectangle, new $85.00
TDY "JAM" RADAR ROTATING ANTENNA. 10 cm. 30 deg. beam. 115 v.a.c. drive. New $100.00
SO-13 ANTENNA, 24" dish with feedback dipole 360 deg. rotation, complete with drive motor and selsyn. New $128.00
Used $45.00
DBM ANTENNA. Dual, back-to-back parabolas with dipoles. Freq. coverage 1,000-4,500 mc. No drive mechanism $65.00
AS125/APR Cone type receiving antenna. 1080 to 3208 megacycles. Now $4.50
140-600 MC. CONE type antenna, complete with 25' sectional steel mast, guys, cables, carrying case, etc. New $49.50
ASD 3 cm. antenna, used, ex. cond $49.50

RADAR SETS

RC 145 IFF SET. Consists of BC 1267 xmtr-revr, remote antenna controller and indicator I-221, power supply RA 105-A. 1 kw. pulse oscillator operates on 154-186 mc. Operates from 117 v., 60 cy. New $190.00
SN RADAR-GE, low power, 5 and 25 miles ranges. Uses GL446 as pulsed oscillator, 5" "A" scope, "S" band. Extremely compact, ideal for demonstration and laboratory work, 115V 60 C operation. Used. Excel. cond. $600.00
SE 10 CM SURFACE SEARCH RADAR. W.E., 20,000 to 80,000 yds. range. 250 KW. pk. power input to 706 magnetron. Thyratron modulator, variable pulse rate. Complete set including spare parts, tubes, waveguide and fittings. Send for price and additional information.
R8STPL-1 RADAR RCVR, Sperry $85.00

Buy with Confidence

MICROWAVE PLUMBING

1.25 CENTIMETER

"K" BAND FEEDBACK TO PARABOLA HORN, with pressurized window $30.00
MITRED ELBOW cover to cover $4.00
TR/ATR SECTION choke to cover $4.00
FLEXIBLE SECTION 1" choke to choke $5.00
ADAPTER, rd. cover to sq. cover $5.00
MITRED ELBOW and S sections choke to cover..$4.50
WAVE GUIDE $^1/_2$ x $^1/_4$ per ft. $1.00
K BAND CIRCULAR FLANGES .....50¢

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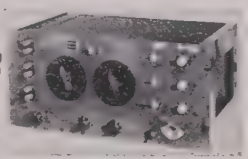
PULSE EQUIPMENT

MODULATOR UNIT BC 1203-B



Provides 200-4,000 PPS. Sweeptime: 100 to 2,500 microsec. in 4 steps, fixed mod. pulse, suppression pulse, sliding modulating pulse, blanking voltage, marker pulse sweep voltages, calibration voltages, fil. voltages. Operates 115 vac. 50-60 cy. Provides various types of voltage pulse outputs for the modulation of a signal generator such as General Radio ‡804B or ‡804C used in depot bench testing of SCR 695, SCR 595, and SCR 535. New as shown $125.00
MIT. MOD. 3 HARD TUBE PULSER: Output Pulse Power: 144 KW (12 KV at 12 amp). Duty Ratio: .001 max. Pulse duration: 5, 1.0, 2.0 microsec. Input voltage: 115 v. 400 to 2400 cps. Uses 1-715-B, 1-829-B, 3-'72's, 1-'73. New $110.00
APQ-13 PULSE MODULATOR. Pulse Width .5 to 1.1 Micro Sec. Rep. rate 624 to 1348 Pps. Pk. pwr. out 35 KW. Energy 0.018 Joules $49.00
TPS-3 PULSE MODULATOR. Pk. power 50 amp. 24 KV (1200 KW pk); pulse rate 200 PPS, 1.5 microsec; pulse line impedance 50 ohms. Circuit—series charging version of DC Resonance type. Uses two 705-A's as rectifiers. 115 v. 400 cycle input. New with all tubes $49.50
APS-10 MODULATOR DECK. Complete, less tubes $75.00
APS-10 Low voltage power supply, less tubes ..$18.50

PULSE NETWORKS

15A—1-400-50: 15 KV, "A" CKT. 1 microsec., 400 PPS, 50 ohms imp $42.50
G.E. ‡6E3-5-2000-50P2T, 6KV, "E" circuit, 3 sections, .5 microsecond, 2000 PPS. 50 ohms impedance .$6.50
G.E. ‡3E (3-.84-810; 8-2.24-405) 50P4T: 3KV, "E" CKT Dual Unit: Unit 1, 3 Sections, .84 Microsec, 810 PPS, 50 ohms imp.; Unit 2, 8 Sections, 2.24 Microsec. 405 PPS, 50 ohms imp. $6.50
7.5E3-1-200-67P. 7.5 KV, "E" Circuit, 1 microsec. 200 PPS, 67 ohms impedance, 3 sections $7.50
7.5E4-16-60-67P. 7.5 KV, "E" circuit, 4 sections, 16 microsec. 60 PPS, 67 ohms impedance $15.00
7.5E3-3-200-6PT. 7.5 KV, "E" Circuit, 3 microsec. 200 PPS, 67 ohms imp., 3 sections $12.50

DELAY LINES

D-168184: .5 microsec. up to 2000 PPS, 1800 ohm term $4.00
D-170499: .25/.50/.75 microsec. 8 KV. 50 ohms imp. $16.50
D-165997: 1¼ microsec. $7.50

PULSE TRANSFORMERS

G.E.K.-2745 .....$39.50
G.E.K.-2744-A. 11.5 KV High Voltage, 3.2 KV Low Voltage @ 200 KW oper. (270 KW max.) 1 microsec. or ¼ microsec. @ 660 PPS $39.50
W.E. ‡D166173 HI-Volt input transformer, W.E. impedance ratio 50 ohms to 900 ohms. Freq. range: 10 kc to 2 mc. 2 sections parallel connected, potted in oil $36.00
W.E. KS 9800 Input transformer. Winding ratio between terminals 3-5 and 1-2 is 1.1:1, and between terminals 6-7 and 1-2 is 2:1. Frequency range: 380-520 c.p.s. Permalloy core $8.00
G.E. ‡K2731 Repetition Rate: 635 PPS. Pri. Imp: 50 Ohms. Sec. Imp: 450 Ohms. Pulse Width: 1 Microsec. Pri. Input: 9.5 KV PK. Sec. Output: 28 KV PK. Peak Output: 800 KW. Bifilar 2.75 Amp. $64.50
W.E. ‡D169271 Hi Volt input pulse Transformer $27.50
G.E. K2450A Will receive 13KV, 4 micro-second pulse on pri., secondary delivers 14KV. Peak power out 100KW GE $45.00
G.E. ‡K2748A Pulse Input, line to magnetron ..$36.00
‡9280 Utah Pulse or Blocking Oscillator XFMR Freq. limits 790-810 cy-3 windings turns ratio 1:1:1 Dimensions 1 13/16 x 1 1/8 x 19/32" $1.50

MISCELLANEOUS

DEHYDRATING UNIT. 60 lb. capacity, 115 v. 60 cy. operation. 2' x 22" x 15". New and complete $425.00
F129 SPP-2, COAX WAVETRAP $12.50

3 CENTIMETER PLUMBING

(STD. 1" x ½" GUIDE, UNLESS OTHERWISE SPECIFIED)

TRANSITION: 1 x ½ to ¼ x ⅝ , 14 in. L $8.00
"X" BAND PREAMPLIFIER, consisting of 2-723 A/B local oscillator-beacon feeding waveguide and TR/ATR Duplexer sect, incl. 60 mc IF amp $67.50
Random Lengths wavegd, 6" to 18" Lg. ...$1.10 Ft.
WAVEGUIDE RUN, 1¼" x ½" guide, consisting of 4 ft. section with Rt. angle bend on one end 2" 45 deg. bend other end $8.00
WAVEGUIDE RUN, 1¼" x ½" guide, consisting of 4 ft. long. $10.00
DUMMY LOAD, Ts 332 UP $22.50
"X" BAND PRESSURIZING gauge section w/15-lbs gauge & Pressurizing Nipple $18.50
45 DEG. TWIST 6" long $10.00
12 SECTION 45 deg twist 90 deg. bend $6.00
11 STRAIGHT WAVEGUIDE section choke to cover Special heavy Construction, silver plated $4.50
15 DEG BEND 10" choke to cover $4.50

5 FT. SECTIONS choke to cover. Silver Plated $14.50

18" FLEXIBLE SECTION $17.50
"F" and "H" PLANE BENDS $12.50
BULKHEAD FEED THRU $15.00
"X" BAND WAVEGUIDE 1¼" x ⅝" OD 1/16" wall Aluminum .....Per Foot $ .75
WAVEGUIDE 1" x ½" I.D. .....Per Foot $1.50
TR CAVITY For 724-A TR Tube $3.50
3" FLEX SECT. sq. flange to Circ Flang Adapt. $7.50
724 TR TUBE (41-TR-1) $2.50
SWR MEAS. SECTION, 4" L with 2 type "N" output probes MTD full wave apart. Bell size guide. Silver plated $10.00
ROTARY JOINT with slotted section and type "N" output pickup $17.50
WAVEGUIDE SECTION, 12" long choke to cover 45 deg. twist & 2½" radius, 90 deg. bend $4.50
SLUG TUNER/ATTENUATOR, W.E. guide, gold plated $6.50
TR/ATR DUPLEXER Sect. w/iris flange $8.00
TWIST 90 deg. 5" choke to Cover w/press nipple $6.50
WAVEGUIDE SECTIONS 2½ ft. long silver plated with choke flange $5.75
WAVEGUIDE 90 deg. bend "E" Plane, 18" Lg $4.00
ROTARY JOINT choke to choke $17.50
ROTARY JOINT choke to choke with deck mounting $17.50
S. CURVE WAVEGUIDE 8" Lg. cover to choke $3.50
DUPLEXER SECTIONS FOR 1B24 .....$10.00
CIRCULAR CHOKE FLANGES solid brass .....$.55
SQ. FLANGES FLAT BRASS .....ea. $.55
APS-10 TR/ATR DUPLEXER section with additional IRIS Flange $10.00
FLEXIBLE WAVEGUIDE .....$4.00/FT.
723 A B Klystrow Mount shielded on X Band Guide with Rough Attenuator Output .....$75.00 ea.

MICROWAVE GENERATORS

AN/APS-15A "X" Band compl. RF head and modulator, incl. 725-A magnetron and magnet, two 723A/B klystrons (local osc. & beacon), 1B24 TR, revr-ampl, duplexer, HV supply, blower, pulse xtmr. Peak Pwr. Out: 45 KW apx. Input: 115, 400 cy. Modulator pulse duration .5 to 2 micro-sec. apx. 13 KV Pk Pulse. Compl. with all tubes incl. 715-B, 829B, RKR 73, two 72's. Compl. pkg., new $210.00
APS-15B. Complete pkg. as above, less modulator $150.00
"S" BAND AN/APS-2. Complete RF head and modulator, including magnetron and magnet, 417-A mixer, TR, receiver, duplexer, blower, etc., and complete pulser. With tubes, used, fair condition $75.00
10 CM, RF Package. Consists of: SO Xmtr.-receiver using 2127 magnetron oscillator, 250 KW peak input. 707 receiver-mixer, rotating yolk PPI for above $150.00
Modulator-motor-alternator unit for above.....$ 75.00
Receiver-rectifier power unit for above.....$ 25.00
Rotating Ant. with parabolic reflector for above. New .....$ 75.00

THERMISTORS

D-167332 (tube) ...$.95
D-170396 (bead) ...$.95
D-167613 (button) ..$.95
D-166228 (button) ..$.95
D-164699 for MTG. in "X" band Guide $2.50
D-167018 (tube) ...$.95

COAX PLUGS

831SP .....$.35
831AP .....$.35
831HP .....$.15
UG 21/U .....$.85
UG 86 U .....$.95
UG 254/U .....$.75

VARISTORS

D170225 .....$1.25
D-167176 .....$.95
D-168687 .....$.95
D-171812 .....$.95
D-171528 .....$.95
D-168549 .....$.95
D-162482 .....$3.00
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GAUSS	POLE DIAM.	SPACING	PRICE
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4850	¾ in.	⅞ in.	$12.50
1860	1⅝ in.	1⅛ in.	$14.50
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* Mfr's Number.

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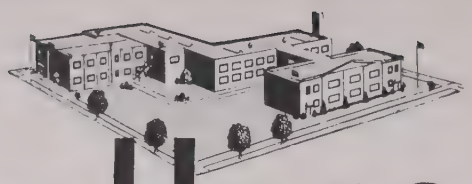
F.O.B. N.Y.C. SEND MONEY ORDER OR CHECK, ONLY SHIPPING CHARGES WITH C.O.D.



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Dept. PR-69 **COLLINGDALE, PENNA.**

SECTION MEETINGS

(Continued from page 34A)

INYOKERN

"Radio the Hard Way," by G. R. Sams, United States Navy; March 30, 1949.

"Summaries of IRE National Convention," by F. M. Ashbrook and T. Parkin, United States Navy; March 30, 1949.

KANSAS CITY

"The Baldwin Electronic Organ," by J. F. Jordan, Baldwin Company; January 12, 1949.

"Stratovision," by A. Nims, Westinghouse Electric Corporation; January 25, 1949.

"Oscillographs and their Application to Industry and Research," by A. Rich, Dumont Laboratories; February 15, 1949.

"Technical and Operational Aspects of the VHF Omni-Range," by F. L. Moseley, Collins Radio Company; March 15, 1949.

LOS ANGELES

"Electronic Applications in Seismic Prospecting," by M. L. Swan, United Geophysical Company; March 15, 1949.

LOUISVILLE

"The Operation of a Modern Television Station," by W. E. Hudson, Radio Station WAVE; April 11, 1949.

MONTREAL

"Creative Technology," by M. J. Kelly, Bell Telephone Laboratories; February 24, 1949.

"An Experimental Design of a Simple FM Receiver," by T. L. Taylor, Student, McGill University; March 9, 1949.

"Link-Coupled Tank Circuits," by R. Tennet, Student Laval University; March 9, 1949.

"Varistors in Negative Feedback Amplifiers," by G. W. Holbrook, Queens University; March 9, 1949.

"An Adjustable Frequency Stroboscope Suitable for Taking Multiple Exposure Photographs," by H. M. Sullivan, Carleton College; March 9, 1949.

"A Radiating Pattern Computor and Phase-Modulating Tube," by L. Pigeon, Student, University of Montreal; March 9, 1949.

"Acoustic Measurements of Broadcasting Studios," by R. E. Santo, Canadian Broadcasting Company; March 23, 1949.

"Television Site Survey Measurements," by J. E. Hayes, Canadian Broadcasting Corporation; March 23, 1949.

"The Selection of Magnetic Core Materials," by H. F. Porter, Magnetic Metals Company; April 6, 1949.

NEW MEXICO

"Telemetering on Power Transmission Lines," by V. B. Wilfey, Westinghouse Electric Company; March 25, 1949.

OTTAWA

"Acoustic Measurement of Broadcast Studios," by R. E. Santo, Canadian Broadcasting Corporation; March 17, 1949.

"Television Site Survey Measurements," by J. E. Hayes, Canadian Broadcasting Corporation; March 17, 1949.

"Some Developments in Direction Finding and the Speed of Radio Waves," by R. L. Smith-Rose, Department of Scientific and Industrial Research; March 31, 1949.

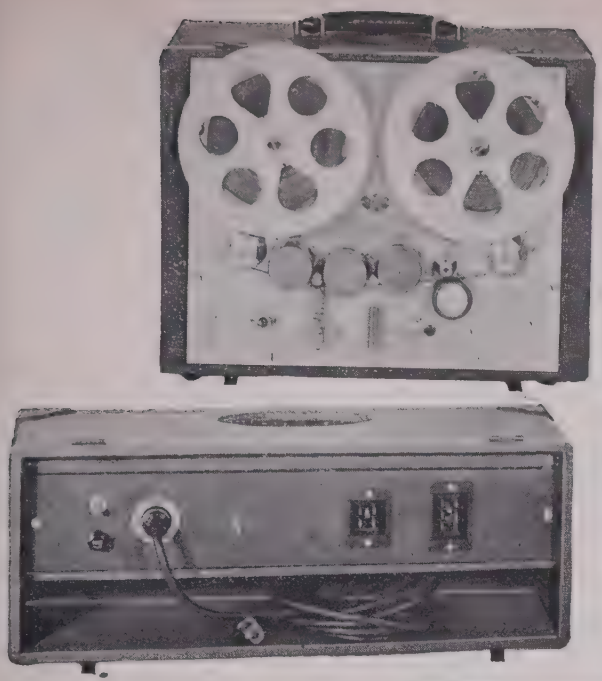
PHILADELPHIA

"Magnetic Amplifiers," by E. Weber, Brooklyn Polytechnic Institute; April 7, 1949.

PORTLAND

"The Radio Engineer Looks at Industrial Electronics," by E. D. Cook, General Electric Company; February 15, 1949.

(Continued on page 38A)



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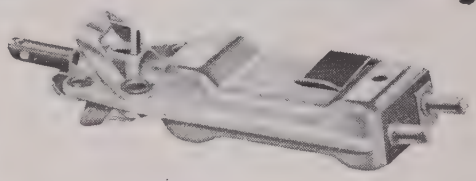
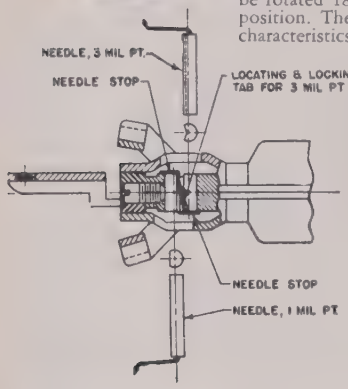


MODEL F-16

The model F-16 is an all-purpose crystal cartridge employing two separate needles to permit playing both fine-cut and standard records . . . with a single tone arm and three-speed turntable. The cartridge can be rotated 180° in the arm to bring the proper needle into playing position. The model F-16 is a quality cartridge with ideal response characteristics.



SPECIFICATIONS

APPLICATION: 33⅓ RPM, 45 RPM and 78 RPM.

TRACKING PRESSURE: 7 grams for all speeds.

CONSTRUCTION: Stamped aluminum half-shells.

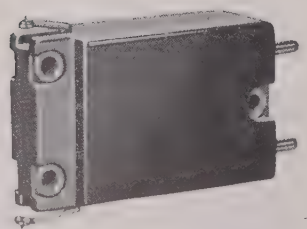
FRONT BRACKET: Extends through front of pick-up arm to permit rotating cartridge 180.°

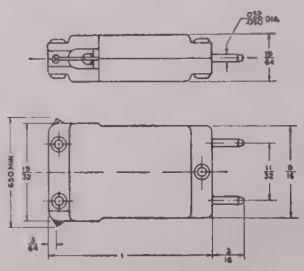
STYLE: Osmium-tipped, replaceable. 1-mil point for 33⅓ and 45 RPM, 3-mil point for standard 78 RPM.

TERMINALS: Pin type, grounded or ungrounded.

OUTPUT: 8 volt for 33⅓ and 45 RPM, 1.2 volts for standard 78 RPM.

MODEL A-1





The Model A-1 crystal cartridge is newly developed . . . miniature in size and ideally adapted for tone arms of modern styling and function. It mounts either a 1-mil or 3-mil point stylus or both, making it applicable to all types of recordings in use today. Tracking pressure is only 7 grams . . . meeting the requirements of 33⅓ and 45 RPM as well as the standard 78 RPM records. Adaptor brackets supplied for mounting in arms originally designed for standard cartridges.

SPECIFICATIONS

APPLICATION: 33⅓, 45 and 78 RPM recordings.

CONSTRUCTION: Bakelite housing.

TERMINALS: Pin type.

STYLI: Osmium- or Sapphire-tipped.

TRACKING PRESSURE: 7 grams.

OUTPUT: 1 volt at 1000 cps.

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(Continued from page 36A)

PRINCETON

"Television Receiver with 16-inch Metal Kinescope," by E. L. Clark, Radio Corporation of America; April 14, 1949.

ROCHESTER

"The Block Signal System for Airways Traffic Control," by H. C. Kendall, General Railway Signal Company; March 24, 1949.

SALT LAKE

"Measurements at Ultra-High Frequencies, by W. R. Hewlett, Hewlett-Packard Company; March 21, 1949.

SAN ANTONIO

"Impedance Matching with Transmission Lines and Waveguides," by F. E. Brooks, Jr., University of Texas; March 21, 1949.

SAN FRANCISCO

"Power Systems Communication," by R. H. Miller, Pacific Gas and Electric Company; March 14, 1949.

TORONTO

"Acoustic Measurements of Broadcasting Studios," by R. E. Santo, Canadian Broadcasting Corporation; March 21, 1949.

"Television Site Survey Measurements," by J. E. Hayes, Canadian Broadcasting Corporation; March 21, 1949.

"CBL—CJBC Transmitters," by J. C. Punchard, Northern Electric Company, Ltd.; April 11, 1949.

TWIN CITIES

"The Mechanism of Electronic Digital Computers," by A. A. Cohen, Engineering Research Associates, Inc.; March 1, 1949.

WASHINGTON

"Electronic Arithmetic," by C. N. Hoyler, RCA Laboratories; April 11, 1949.

SUBSECTIONS

LANCASTER

"A Record Changer and Record of Complimentary Design," by A. D. Burt and H. I. Reiskind, RCA Victor Division; April 6, 1949.

Election of Officers; April 6, 1949.

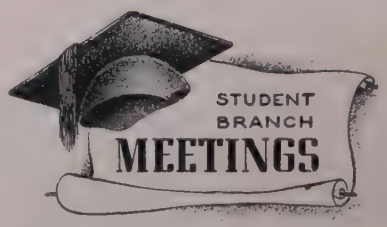
LONG ISLAND

"Intercarrier Sound Television Receiver Circuits," by S. W. Seeley, Radio Corporation of America; February 16, 1949.

NORTHERN NEW JERSEY

"Nuclear Energy," by K. K. Darrow, Bell Telephone Laboratories; March 23, 1949.

"The Ampex Magnetic Tape Recorder," by W. O. Summerlin, Audio and Video Products Corporation; March 23, 1949.



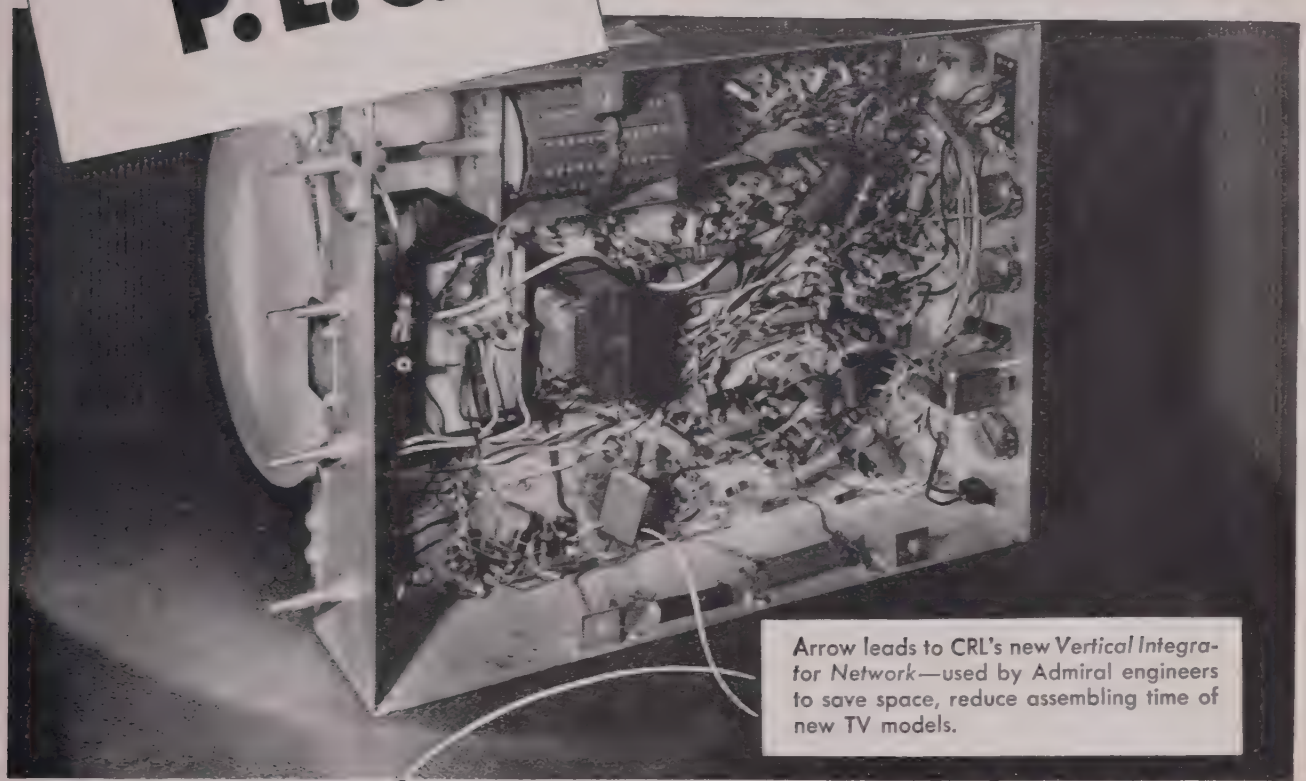
UNIVERSITY OF ALBERTA, IRE BRANCH

"The Value of Education in Engineering," by R. M. Hardy, Dean of Faculty of Engineering, University of Alberta; March 15, 1949.

(Continued on page 40A)

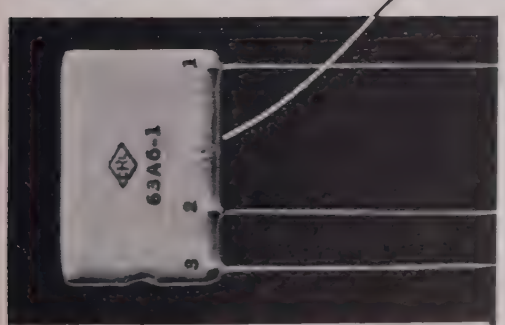
PROGRESS REPORT ON P.E.C.*

How Admiral is using CRL's new "P. E. C." *Vertical Integrator Network* to help build more and finer television sets

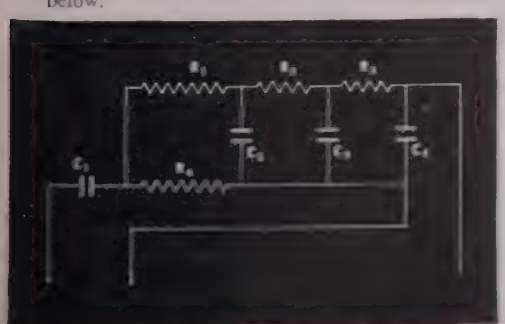


Arrow leads to CRL's new *Vertical Integrator Network*—used by Admiral engineers to save space, reduce assembling time of new TV models.

Chassis courtesy of Admiral Corp.



This is the new CRL *Vertical Integrator Network* used by Admiral, variations of which are available on special order. Circuit diagram of "network" used in new Admiral TV sets is shown below.



*Centralab's "Printed Electronic Circuit" — Industry's newest method for improving design and manufacturing efficiency!

WHEREVER Centralab's revolutionary Printed Electronic Circuits are used, you are sure to find speeded production . . . quality products. Just look at Admiral Corporation's fine new television receivers. A series of Admiral's video sets makes use of CRL's *Vertical Integrator Network* — a tiny, compact plate containing both capacitors and resistors. It saves production time . . . reduces sixteen soldered connections to three. Simplifies wiring operations for faster assembly. What's more, the *Network* helps produce better TV receivers . . . practically eliminates loose or broken connections.

Integral Ceramic Construction: Each *Printed Electronic Circuit* is an integral assembly of *Hi-Kap* capacitors and resistors closely bonded to a steatite ceramic plate and mutually connected by means of metallic silver paths "printed" on the base plate.

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STUDENT BRANCH MEETINGS

(Continued from page 38A)

UNIVERSITY OF CALIFORNIA SOCIETY OF ELECTRICAL ENGINEERS, IRE-AIEE BRANCH

"Silicones and their Application to Transformers," by M. L. Manning, Kuhlman Electric Company; March 2, 1949.

CASE INSTITUTE OF TECHNOLOGY, IRE BRANCH

"Television," by E. M. George, WXEL (TV); March 1, 1949.

"Synthetic Piezoelectric Crystals," by Mr. Arnst, Brush Development Company; March 15, 1949.

COLUMBIA UNIVERSITY, IRE-AIEE BRANCH

"Selenium Rectifiers," by Mr. Lobenstein, Selenium Rectifier Division of Radio Receptor Corporation; March 25, 1949.

UNIVERSITY OF DAYTON, IRE BRANCH

"Television Receivers," by W. Horst, Student, March 1, 1949.

"Colored Television," by D. Moore, Student; March 8, 1949.

"Telephony," by B. O'Brien, Student; March 15, 1949.

"Strowger System," by J. Quinlisk, Student; March 22, 1949.

"Telephone Trouble Shooting," by E. Johnson, Student; March 29, 1949.

UNIVERSITY OF DETROIT, IRE-AIEE BRANCH

"FM versus AM," by E. Clark, Radio Station WJLB, R. MacDonald, Radio Station WJR, C. Wesser, Radio Station WWJ, C. Kocher, Radio Station WXYZ, L. West, Radio Station WDET, J. F. Steadley, Radio Station WLDM and C. Dook, Radio Station WTDR; January 6, 1949.

"Technical Problems in the Broadcasting Studio," by A. Friedenthal, Radio Station WJR; March 9, 1949.

"Industrial Applications of Television," by J. Good, Diamond Power Specialties Company; March 29, 1949.

UNIVERSITY OF FLORIDA, IRE-AIEE BRANCH

"The Development of the Scientific Method in Physics," by S. Dushman, General Electric Company; March 23, 1949.

GEORGE WASHINGTON UNIVERSITY, IRE BRANCH

"Telemetering," by W. J. Mayo-Wells, John Hopkins University; March 2, 1949.

STATE UNIVERSITY OF IOWA, IRE BRANCH

"Symmetrical Components," by C. Lodge, Graduate Assistant; March 16, 1949.

LAFAYETTE COLLEGE, IRE-AIEE BRANCH

"Difficulties of Long-Range Television Reception," by D. Berk, Student; March 10, 1949.

"Series Computers," by D. Seib, Student; March 10, 1949.

"Wire Recorder," by J. Wright, Student; March 10, 1949.

UNIVERSITY OF MAINE, IRE BRANCH

"New Type of FM Detector," by P. Howells, Faculty staff; March 17, 1949.

"Nockel-Cadmium Batteries," by N. B. Hamlin, Student; March 17, 1949.

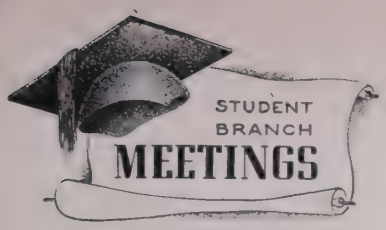
"Illumination—Development of Lamps and their Applications," by R. G. Slauer, Sylvania Electric Products Company; April 14, 1949.

Election of Officers; April 14, 1949.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

"Electric Power Systems," by G. Orrok, Boston Edison Company; March 23, 1949.

(Continued on page 41A)



(Continued from page 40A)

"Industrial Research," by M. J. Kelley, Bell Telephone Laboratories; April 6, 1949.

UNIVERSITY OF MICHIGAN, IRE-AIEE BRANCH

"Engineering Opportunities," by J. R. North, Commonwealth and Southern Corporation; March 23, 1949.

Election of Officers; March 23, 1949.

MISSOURI SCHOOL OF MINES, IRE-AIEE BRANCH

"Investigation of a Uniformly-Inductively Loaded Antenna," by E. L. Hughes, Student; March 23, 1949.

"Application of Tensor Analysis to Synchronous Machines," by P. F. Schaefer, Student; March 23, 1949.

UNIVERSITY OF NEBRASKA, IRE-AIEE BRANCH

"Power Production from Nuclear Chain Reaction," by T. Jorgensen, University of Nebraska; April 6, 1949.

NEWARK COLLEGE OF ENGINEERING, IRE BRANCH

"Psycho-Acoustics," by D. C. Spitz, Student; March 25, 1949.

UNIVERSITY OF NEW MEXICO, IRE BRANCH.

"Antennas at Optimum Frequencies," by T. C. Church and B. J. Bittner, Sandia Base Laboraton; February 17, 1949.

CITY COLLEGE OF NEW YORK, IRE BRANCH

"Television Receiver Problems," by B. M. Cole, North American Philips Company, Inc.; March 29, 1949.

NEW YORK UNIVERSITY, IRE BRANCH

"Radar Systems," by R. Shetzline, Bell Telephone Laboratories; April 6, 1949.

UNIVERSITY OF NORTH DAKOTA, IRE-AIEE BRANCH

Election of Officers; February 16, 1949.

"Personnel Work," by C. E. Scott, University of North Dakota; March 16, 1949.

UNIVERSITY OF NOTRE DAME, IRE-AIEE BRANCH

"Electronics in the Electric Utility Field," by E. F. Kenefake, General Electric Company; February 23, 1949.

"Patent Law," by E. Knoblock, Patent Attorney; March 25, 1949.

PRATT INSTITUTE, IRE BRANCH

"Infinite Q Filters," by W. Heacock, Student; February 24, 1949.

"Wave Theory of Matter," by O. Shuart, Student; March 10, 1949.

ST. LOUIS UNIVERSITY, IRE BRANCH

"What is Expected of the Graduate Engineer in Industry," by W. Bennettsen, Emerson Electric Manufacturing Company; March 10, 1949.

Election of Officers; March 24, 1949.

"Illinois State Police Communications," by W. Friedrich, Student; March 31, 1949.

SYRACUSE UNIVERSITY, IRE-AIEE BRANCH

"Expansion in the Power Field," by Mr. Pratt, New York Central Power Company; March 9, 1949.

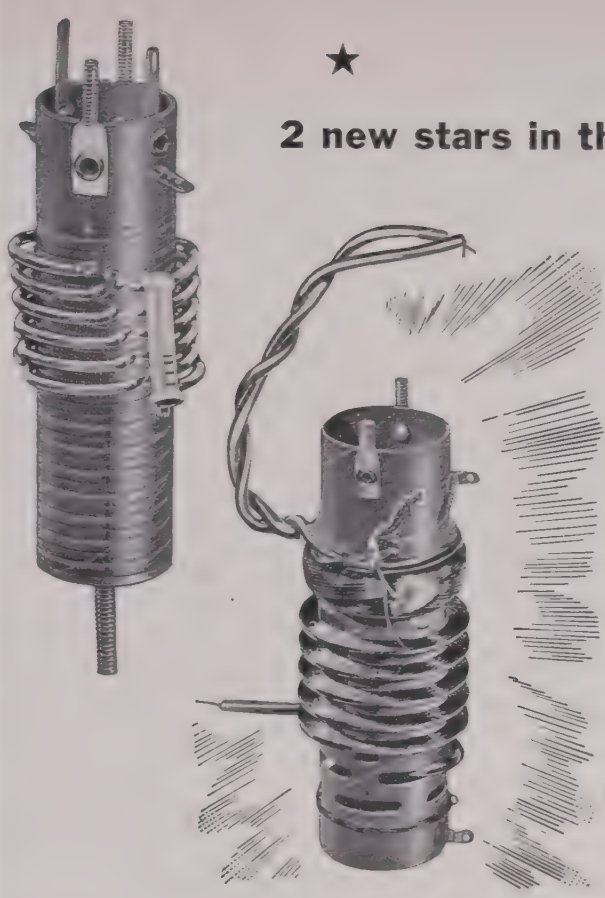
"Electronics in the Utility Field," by E. W. Kenefake, General Electric Company; March 30, 1949.

Election of Officers; March 30, 1949.

UNIVERSITY OF TENNESSEE, IRE BRANCH

"Recent Developments in Electrical Engineering," by P. C. Cromwell, University of Tennessee, February 22, 1949.

(Continued on page 42A)



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HERE is a comprehensive, practical reference volume on basic sound problems for the designer, operating engineer or technician.

The authors discuss in detail those subjects that belong to the restricted field of sound recording and reproduction, and which are not discussed in books devoted to the allied fields of electronics, radio engineering, etc. However, since those interested in studying sound recording have widely different kinds of training and experience, some closely related subjects such as electromechanical analogies, acoustics, vacuum tubes, and audio amplifiers are discussed.

The book includes—

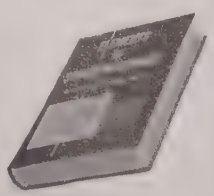
A large number of numerical examples to make the design procedure perfectly clear to the reader.

More than 480 diagrams and photographs illustrating every step of the text material.

Contents:

Nature of Sound, Sound Waves and their Perception. Electrical, Acoustical, and Mechanical Circuits. Microphones and Their Uses. Vacuum Tubes. Audio Amplifiers. Network Theory. Attenuators. Filters. Equalizers. Compression and Limiting. Recording Systems. Electrical Measurements. Principles of Disk Recording. Disk Records and Their Processing. Fundamental Principles of Variable-Density Recording. The Light Valve. Variable-Intensity Modulators. Principles of Variable-Area Recording. Variable-Area Modulators. Noise-Reduction Methods. Intermodulation Test Methods. Flutter and Its Measurement. Film and Disk Drive Mechanisms. Motor Drive Systems. Film Laboratory Processes. Re-recording. 35-mm Motion-Picture Recording Systems. 16-mm Sound Film Systems. Magnetic Recording. Loudspeaker Systems. Acoustics of Stages and Theatres. Stereophonic Recording.

May 1949
686 pages
483 illus.
$8.50



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City .....Zone .....State .....
(Offer not valid outside U.S.) IRE-6-49

Student Branch Meetings

(Continued from page 41A)

THE UNIVERSITY OF TEXAS,
IRE-AIEE BRANCH

"Installation of a 138 Kv Cable," by J. Foley, City Public Service Board of San Antonio; February 7, 1949.

"Mobile Telephone System in Austin," by M. Bassford, W. Graves, and R. Via, Southwestern Bell Telephone Company; February 21, 1949.

"Presentation of Student Papers—AIEE Technical Paper Contest," by C. C. Young, L. F. Bell, K. H. Powers, D. W. Spence, G. B. Wright, E. D. Lovelady, and Herman Willi, Students; March 7, 1949.

"Impedance Matching in Wave Guides," by F. E. Brooks, The University of Texas; March 21, 1949.

UTAH STATE AGRICULTURAL COLLEGE,
IRE BRANCH

"Teletype," by F. Gunnell, Bell Telephone System; March 30, 1949.

WORCESTER POLYTECHNIC INSTITUTE,
IRE-AIEE BRANCH

Election of Officers; March 22, 1949.

The following transfers and admissions were approved and will be effective as of June 1, 1949:

Transfer to Senior Member

Barclay, J. N., 2915 Red River St., Austin 22, Tex.
Clewell, D. H., Magnolia Petroleum Co., Box 900, Dallas, Tex.
Dobosy, J. F., 31748 Lake Rd., Avon Lake, Ohio
Gambel, E. H., Curtiss-Wright Corp., 4300 E. Fifth Ave., Columbus 16, Ohio
Grimwood, F. O., 1325 N. Sixth St., Quincy, Ill.
Hershfield, S., 5 Glenwood Rd., Essex, Baltimore 21, Md.
Kean, W. F., 114 Northgate Rd., Riverside, Ill.
Muchmore, R. B., 571½ Oxford Ave., Hawthorne, Calif.
Parker, B. E., 338 S. 12 St., Quincy, Ill.
Pasek, D. M., 255-04 West End Dr., Great Neck, L. I., N. Y.
Peake, H. J., 715 S. Washington St., Alexandria, Va.
Watts, H. M., Radiation Laboratory, The Johns Hopkins University, Baltimore 2, Md. (Effective December 1, 1948)

Admission to Senior Member

Bischoff, A. F. H., 44 Hyde Blvd., Ballston Spa, N. Y.
Corrington, M. S., 12 E. Cottage Ave., Haddonfield, N. J.
Murphy, O. J., 410 Central Park West, New York 25, N. Y.
Townsend, F. H., 21 Park Lane, Histon, Cambs., England
Young, F. C., 100 Carlson Rd., Rochester 3, N. Y.

Transfer to Member

Buehler, F. A., 665 W. Warren Ave., Detroit 1, Mich.
Carlstrom, T. H., Sylvania Electric Products, Inc., Emporium, Pa.
Davidson, H. H. A., 1376 Esquimalt Rd., Esquimalt, B. C., Canada
Ghose, A., Government Engineering College, Jubbulpore, India
Hillyer, C., 54-60 Lafayette St., New York 13, N. Y.
O'Donnell, J. A., 63 Wyneva St., Philadelphia 44, Pa.

(Continued on page 43A)

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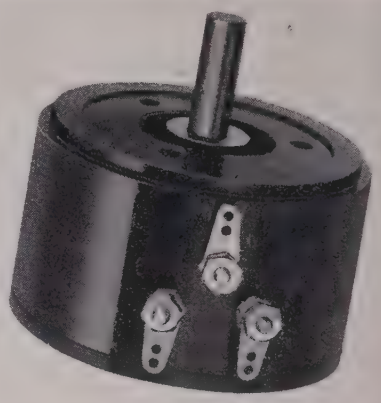

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(Continued from page 42A)

Oszy, A. J., 149–56 Elm Ave., Flushing, L. I., N. Y.
Robertson, A. S., 10 W. 48 St., New York 19, N. Y.
Schwab, C. B., 508—19 St., N.W., Massillon, Ohio
Shrock, J. B., Sandia Base Branch, Albuquerque, N. M.
Striplin, J. E., 2713 W. 154 St., Gardena, Calif.
Tilly, V. F., 31195 Merriman Pl., Inkster, R.F.D. 3, Mich.
Vane, A. B., 128 Blackburn Ave., Palo Alto, Calif.
Vought, N. F., 7455—64 Lane, Glendale, L. I., N. Y.
Walchli, H. E., 144 Waddell Circle, Oak Ridge, Tenn.
Webster, N. D., 515 Blackwood, N. Sacramento, Calif.
Weedman, W. F., 2712 Second St., S. E., Washington 20, D. C.
Wheeler, W. R., 8330 Kew Gardens Rd., Kew Gardens, N. Y.

Admission to Member

Bibbero, R. J., 773 Potomac Ave., Buffalo 9, N. Y.
Biberman, L. M., 103 Mitscher Rd., China Lake, Calif.
Bright, F. W., 630 Randolph St., Dayton 8, Ohio
Carman, W. H., Station KOAT, Box 1419, Albuquerque, N. M.
Cotton, A. F. R., 2145 California St., N.W., Washington 8, D. C.
Dibos, R. A., 732 Charles St., Glenside, Pa.
Doane, H. J., 1851 AACS Liaison Unit, R.C.A.F., Station, Edmonton, Ala., Canada
Ewing, D. L., 309B Fowler, China Lake, Calif.
McCluskey, V., 5 W. 63 St., New York 23, N. Y.
Nelson, C. V., Ipswich Rd., East Boxford, Mass.
Purinton, R. M., 127 St. & Archer Ave., Lemont, Ill.
Rohrer, R. E., 1339 Wisconsin Ave., N.W., Washington 7, D. C.
Scott, H. G., Box 35, Glebe, N.S.W., Australia
Yewell, P. G., Box 102, West Medway, Mass.

The following admissions to Associate were approved and were effective as of May 1, 1949:

Altmann, S., 264 W. 22 St., New York 11, N. Y.
Amick, R. H., 20070 Shiawassee, Detroit 19, Mich.
Angus, D. G., 117 E. Colorado St., Pasadena, Calif.
Argall, G. J., 1527 W. Rosemont Ave., Chicago 26, Ill.
Benson, G. G., 3915 N. State St., Jackson, Miss.
Berry, R. E., General Electric Co., Owensboro, Ky.
Bhargava, A. N., 30 Civil Lines, Roorkee, U.P., India
Borgelt, E. H., 742 Greenlawn Ave., Dayton 3, Ohio
Brooks, J., 1222 D St., N.W., Washington, D. C.
Campbell, D. H., 2216½ Ewing St., Los Angeles 26, Calif.
Chambers, A., 2 Main St., Passaic, N. J.
Close, E. F., 2153 W. LeMoyne, Chicago 22, Ill.
Codey, M. T., 119 E. 42 St., Covington, Ky.
Creighton, C. C., Sixth Radar Calibration Detachment, APO 942, c/o Postmaster, Seattle, Wash.
Cunetta, J. M., 314 Linden Blvd., Brooklyn 26, N. Y.
Dawson, A. W., 234 Charles St., Painted Post, N. Y.
Dolde, L. A., 9036 Cedros Ave., Van Nuys, Calif.
Elfving, A. L., Research Institute of National Defense, Stockholm 61, Sweden
Fairchild, F. E., 446 W. 38 St., New York 18, N. Y.
Fishman, S., 315 Chicago Ave., Dayton, Ohio
Fogg, G. E., Hotel Warner, Emporium, Pa.
Fonte, G., The Clough-Brengle Co., 6014 Broadway, Chicago 40, Ill.
Fujimoto, K. K., 4147 Drexel Blvd., Chicago 15, Ill.
Greathouse, D. E., 710 Poplar St., Waukegan, Ill.
Hagman, H. B., Commercial Engineering Department, Sylvania Electric Products, Inc., Emporium, Pa.
Herrman, R. F., 41 W. 82 St., New York 24, N. Y.
Holpuch, D. J., 3625 Arthur Ave., Brookfield, Ill.

(Continued on page 44A)

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TYPES	IMPEDANCE	LOSS
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By EDWARD W. KIMBARK
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Jackson, T. T., Department of Electrical Engineering, Pennsylvania State College, State College, Pa.
Johnson, H. B., 4426 Park Ave., Kansas City, Mo.
Kafka, N., 610 S. 23 Ave., Bellwood, Ill.
Kubitz, E. H., 5141 S. Mayfield Ave., Chicago 38, Ill.
LaGasse, S. G., 1068 Newby St., Glendale 1, Calif.
Larsson, N. H., Research Institute of National Defense, Stockholm, Sweden
LaRue, R. S., Physics Department, The University of Connecticut, Storrs, Conn.
Laudenslager, R. L., University of Connecticut, Storrs, Conn.
Lee, J. P., 1013 Bergenline Ave., Union City, N. J.
Lovick, R. C., 303 Oaklawn Dr., Rochester 12, N. Y.
Maginniss, F. J., Central Station Engineering Division, General Electric Co., Schenectady, N. Y.
Mahren, A. A., 5602—187 St., Flushing, N. Y.
Marshall, K. C., 151 Strand Lane, Radcliffe, Lancashire, England
Martin, G. E., 4655 Felton, San Diego 4, Calif.
McCoy, O. Z., 515 Aberdeen Ave., Dayton 9, Ohio
McKee, D. M., 218 Wabash Ave., Lansdowne, Pa.
McKinley, J. G., West Pennsylvania Power Co., Box 1736, Pittsburgh 30, Pa.
Morrison, G. B., 3749 N. Nottingham Ave., Chicago 34, Ill.
Murphy, E. J., 960 E. Tioga St., Philadelphia 34, Pa.
Nolen, J. F., 1909—37 St., N.W., Washington 7, D. C.
Pate, W. R., Cottage 658, Crooked Lake, Angola, Ind.
Peterson, A. E., Jr., 30-M Garden Terrace, North Arlington, N. J.
Regan, C. R., c/o Navigational Aids, Electronics Test, Patuxent River, Md.
Schlehlein, G. J., 3005 W. Capitol Dr., Milwaukee 10, Wis.
Schwalbe, M. I., Nichols Veterans Hospital, Louisville 2, Ky.
Sinnott, J., 4313 Ninth Ave., Brooklyn 32, N. Y.
Snyder, H., Box 753, Marietta College, Marietta, Ohio
Soltesz, E. S., 350 Gavin St., San Diego 2, Calif.
Spicer, W., 136 Hastings St., Brookville, Pa.
Stimmel, R. G., 725 Patterson Rd., Dayton 9, Ohio
Thatcher, R., 1728 S. Mansfield Ave., Los Angeles 35, Calif.
Tomberg, S., 97 Patterson Village Dr., Dayton 9, Ohio
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Votocek, J., 2511 S. Harding Ave., Chicago 23, Ill.
Wamboldt, H., 601 Meyer Ave., Dayton 3, Ohio
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Wellinghoff, J. C., 3725 N. Wilton Ave., Chicago 40, Ill.
Weiger, H. O., 4814 N. Lowell Ave., Chicago 30, Ill.
Wikland, T., Research Institute of National Defense, Stockholm, Sweden
Williams, E., 10 Vivian St., Bexley, Sydney, N.S.W., Australia
Wilson, W. D., 54 Wendell Ave., Pittsfield, Mass.
Zito, A. J., 2220 Fish Ave., New York 67, N. Y.

The following transfers to the Associate grade were approved to be effective as of March 1, 1949:

Bayley, R. M., 6046 Roy St., Los Angeles 42, Calif.
Berger, M., 3733 Laurel Ave., Brooklyn 24, N. Y.
De Agazio, E., Jr., 31 Belmont Pk., Everett 49, Mass.
Geppert, D. V., E. B. 207, University of Arkansas, Fayetteville, Ark.

(Continued on page 45A)

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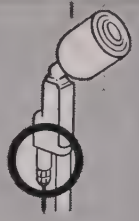

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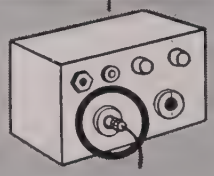

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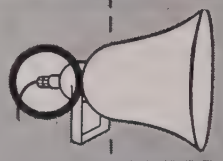

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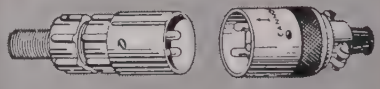

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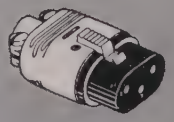

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Janislawski, A. G., c/o Tung-Sol Lamp Works, Inc., Dept. 170, Weatherly, Pa.
Knickel, E. R., Electronics Office, Naval Shipyard Boston, Mass.
Krueger, R. E., Box 1663, Los Alamos, N. M.
Laskin, H. J., 395 Belmont Ave., Brooklyn 7, N. Y.
Lawler, J. A., Jr., 268 Bowman Ave., Merion Station, Pa.
Miller, N. D., Box 95, Epworth, Iowa
Miller, P. G., 322 W. Cervantes St., Pensacola, Fla
Mitchell, A. V., Rm. 2100, 32 Sixth Ave., New York 13, N. Y.
Pomon, J. D., 4536 N. Magnolia, Chicago 40, Ill.
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Robinson, M. P., Jr., 30 Hawthorne St., Watertown 72, Mass.
Rosett, E. S., 35 Brookdale Ave., New Rochelle N. Y.
Russell, J. A., III, Winoka Village, Apt. 22D, Huntington Station, L. I., N. Y.
Shea, E. T., 1516 Darby Rd., Havertown, Pa.
Smit, J., Rua Capt. Salo Mao, S. Paula, Brazil
Stribling, J. L., Jr., 915 N. Jefferson, San Angelo Tex.
Walker, R. C., Box 414, Bucknell University, Lewisburg, Pa.

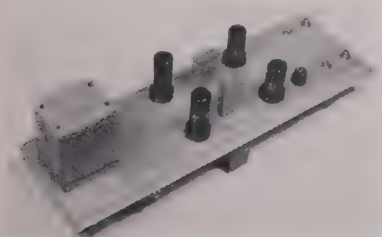
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 26A)

Utility TV Amplifier

A new utility video amplifier, model 4TV17A1, for two-channel general-purpose use as a line or monitoring amplifier and as a line amplifier and supersync mixer, has been announced by **General Electric Co., Transmitter Div.,** Electronics Park, Syracuse, N. Y.



The 4TV17A1 is useful in raising remote programs as low as 1.2 volts up to the standard 2.0 volts for transmission. Either of the two channels can be used with a 75-ohm matched input, or with high impedance bridging the input for monitoring a line.

Low-frequency response on the unit will pass 25% negative 60-cps square wave with over-all tilt of 2% or less on a single channel, and 1% or less with both channels used in parallel. High-frequency response is flat within ±0.6 db to 7 megacycles.

Power input is 115 volts, 50 to 60 cps. The amplifier is designed for vertical rack mounting and is 5¼" high by 19" wide by 7" deep.

(Continued on page 46A)

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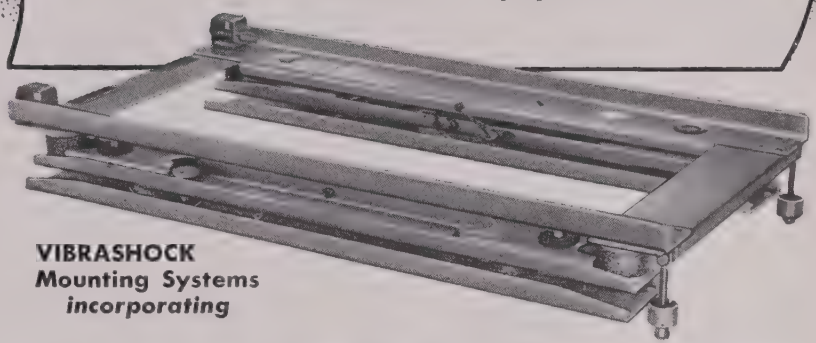

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Vibrashock Mounting Systems with Met-L-Flex are available in standard Form Factors and designs for special applications. See how completely they can answer your vibration control problems.

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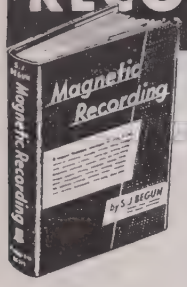

By S. J. Begun
Chief Engineer, The Brush Development Co.

242 pages, 6 x 9, 130 illus., $5.00

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Acoustic and magnetic factors are carefully explained. A-C and D-C biasing methods, distortion factors, reproducing heads, drive mechanisms and the various recording media and methods of recording, reproducing, and erasing are discussed in detail. Particularly valuable are a complete outline of recording devices and how they are used; a helpful study of instruments for determining recording performance; and a clear discussion of magnetic versus other recording methods. More than 130 diagrams and illustrations make things easily understandable. Use coupon for 10 days' free trial.

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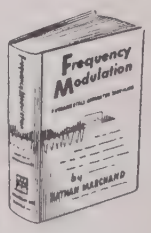

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News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 45A)

Beginning with this issue, the **News and New Products column** will describe as many as possible of the components and completed units which were labeled with "SPOTLIGHT THE NEW" posters at the 1949 IRE National Convention in New York City, on March 7–10.

One idea, which was used by two well-known manufacturers in this industry, was the immersion of equipment in large water-filled containers with gold fish swimming in them to demonstrate the quality and performance of these products in the most adverse conditions of humidity.

The **Commercial Sales Div., DeJur-Amsco Corp.,** 45–01 Northern Blvd., Long Island City 1, L. I., N. Y., employed this idea to exhibit their sealed meters, models 112 and 120. Six meters, each housing a photoelectric cell, were submerged in the bowl of water. They were so arranged that, when a beam of light directed on them was broken, the arrow in each would fluctuate according to the change in light intensity. The fish would break these beams as they swam through the water, causing a constant oscillation of the meter arrows. This protracted submersion and continued performance indicated that these meters were sealed and water tight.

For further information on these meters and the complete line of **DeJur** precision instruments, meters, potentiometers, and rheostats in a range from 10 to 1,000,000 ohms, contact the Commercial Sales Div.

The other firm to make use of this novel type of demonstration was the **General Electric Co., Electronics Dept.,** Electronics Park, Syracuse, N. Y.

To check maximum humidity effect on a standard model record player, pick-up cartridge, and loudspeaker, GE engineers placed them in a tank of water with no harmful effects.

Later is was decided that this test could be used as a demonstration at the IRE Convention. Gold fish, and a small loudspeaker which acted as a microphone, were added. The small speaker picked up the sound of music being played and released it through an external speaker, showing that the complete link went through the water, and two speakers, as well as the cartridge, actually functioned while emersed.

The fish displayed no ill effects from this perpetual serenade, but avoided the immediate area of the speaker, probably due to the increase in vibration.

(Continued on page 47A)

ANNOUNCING A NEW 8" SPEAKER WITH A NEW HARD-HITTING RANGE

JIM LANSING SIGNATURE

8" SPEAKER

100 TO 12,000 C. P. S.

WHERE QUALITY REPRODUCTION IS A "MUST" and space is at a premium—the Jim Lansing 8" Speaker answers the problem! High efficiency and good over-all performance. For improved radio, phonograph and custom television sound reproduction. Designed especially for commercial or industrial use. Ideal for music distribution and paging systems. At all better dealers and distributors.

MODEL D-1002
Two-Way System

For FM monitoring and high quality home sound reproduction. Console type cabinet.

See your Jobber or write to:

JAMES B. LANSING SOUND INC.
2439 Fletcher Drive
Los Angeles, California

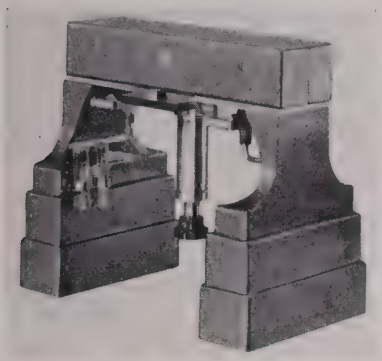
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 46A)

A New Alpha Counter

A new methane-flow proportional counter, Model D45, has been designed to count alpha particles in the presence of high beta activity with 50% geometry and low coincidence losses, by **Nuclear Instrument & Chemical Corp.**, 223 West Erie St., Chicago 10, Ill.



When the D45 is used with a high-gain linear amplifier and a "fast" scaler, it is possible to count alpha particles in the presence of a beta activity of 5×10^9 disintegrations per minute.

The counter chamber has a polished cylindrical cathode. The anode is 0.002" tungsten wire mounted between glass insulators. The sample holder is designed for standard 1" diameter samples, with provisions for raising the sample up into the counting volume for improved geometry.

Recent Catalogs

• • • A new catalog, No. 49, describing the complete line of resistors, controls, and resistance devices manufactured by **Clarostat Mfg. Co., Inc.**, Washington St., Dover, N. H., is ready for distribution.

• • • A new 4-page folder in color illustrates and describes various tube-testor models by **Hickok Electrical Instrument Co.**, 10541 Dupont, Cleveland 8, Ohio.

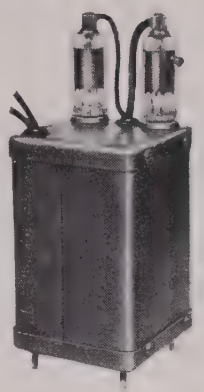
• • • A 4-page circular, entitled "Switches by Daven," with general information on switches used in broadcast, communications, and industrial fields, and in laboratory tests, is issued by the **Daven Co.**, 191 Central Ave., Newark, N. J.

• • • A new 4-page condensed catalog, which may be used as a brief guide for high-speed electronic counters, scalers, counter chronographs, and special electronic frequency-measuring computing equipment is offered by the **Potter Instrument Co., Inc.**, 136–56 Roosevelt Ave., Flushing, L. I., N. Y.

(Continued on page 48A)

Special

TRANSFORMERS

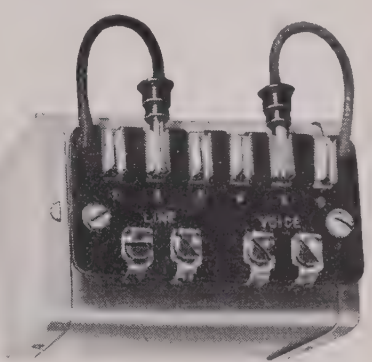


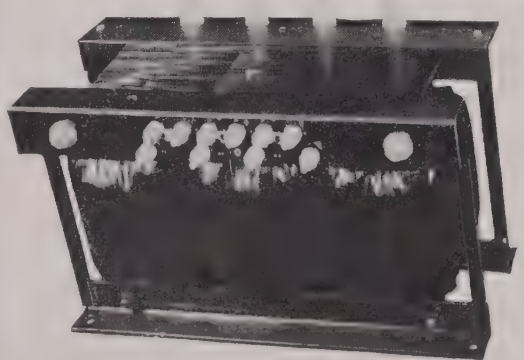
Above: Special DC power supply unit, input 115 volts 60 cycles—output 2500 volts filtered DC at 5 MA.

Right: A high quality speaker line auto transformer, used in multiple speaker installations to adjust volume and impedance for each individual speaker.

TO MEET UNUSUAL SPECIFICATIONS

The manufacture of "tailor-made", one-of-a-kind transformers, and small runs of custom-made specialty units, are important features of NYT service. A staff of engineering and production experts will translate your most exacting specifications into the components you require.





Left: A three phase high voltage plate transformer, weighing over 300 pounds. Rectifier output is 11 KVA DC (7000 volts at 1.5 amps).

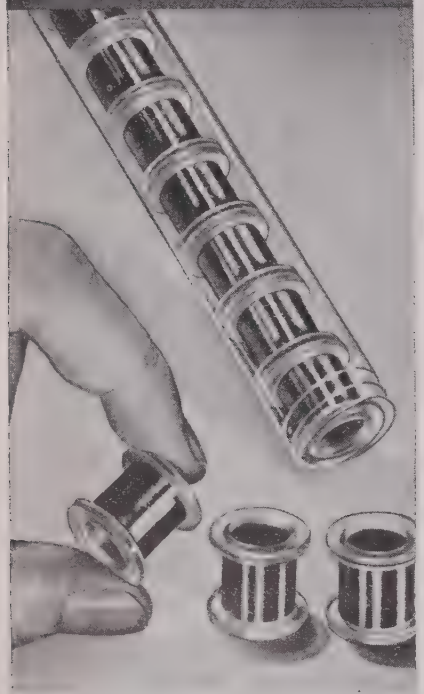
The transformers illustrated show only three of the many which have been developed or manufactured by New York Transformer Company for special applications in radio, television and electronics. No matter how unusual your specifications, NYT will build transformers to meet them! Special facilities also include the manufacture of hermetically sealed units to meet current JAN T-27 and other government specifications; and specially treated, lightweight, uncased units for airborne equipment.

Let us know about your specifications and development problems. NYT experts and engineers are at your service.

NEW YORK TRANSFORMER CO., INC.
ALPHA, NEW JERSEY

Etched
TUNGSTEN
WIRE

.00015" diameter
and smaller



- Accurate, uniform and smooth . . .
- Also available in Molybdenum and other metals . . .

Write for details and List of Products

SIGMUND COHN CORP.
44 GOLD ST. NEW YORK
SINCE 1901

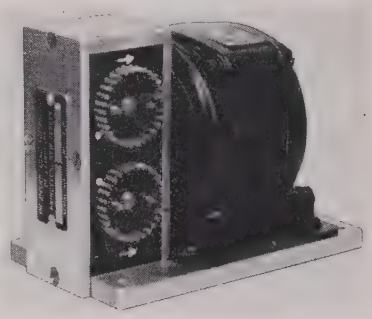
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 47A)

Multichannel Switch

The development of a new multichannel switch, driven by a 60-cps synchronous motor, has been announced by the **Applied Science Corp. of Princeton,** Princeton,

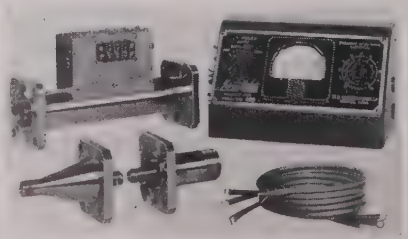


N. J. The use of a synchronous motor assures constant sampling rates and allows the convenient use of an ac line voltage source whose frequency is automatically synchronized with the sampling operation. The 4-pole model shown is 2″×3″×4″ in physical size and has 30 contacts per pole. The wiper is one of the shorting type for flexibility of use. Standard models have sampling rates of 720, 360, 240, 180, or 90 rpm.

These switches facilitate investigation of a large number of separate quantities or of a single quantity under a number of different conditions. In addition to telemetering applications, they may be used for the display of characteristic curves and multichannel voltage comparison. Electrical operations may be synchronized with mechanical motion by appropriate attachment of switch rotor.

Rf Power and SWR Meter

An rf power and SWR meter, with a range of 50 to 500 Mc., has been designed and developed by **M. C. Jones Electronics Co.,** 96 N. Main St., Bristol, Conn.

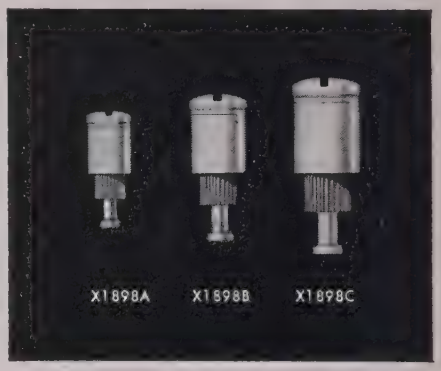


The manufacturer claims that this is the first frequency-insensitive directional coupler to be produced by the industry.

This model, MM400, is one of a series of wide-frequency-range instruments for measuring rf power and standing-wave ratio on 51.5-ohm coaxial transmission line.

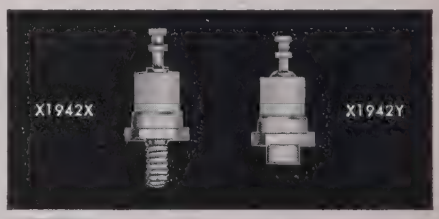
(Continued on page 49A)

TWO NEW
CTC TERMINALS
PROMISE IMPROVED WIRING



1. ***New Combination Terminal In 3 Sizes Has Variety of Uses***

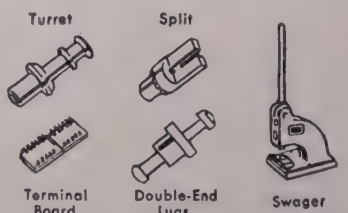
With a screw on top and a terminal lug on the bottom, this combination simplifies top and bottom wiring. Remove the screw and you can mount components directly to the screw end. Or, you can adapt this terminal to provide removable link connections at the screw end. Terminal is plated with bright alloy for corrosion resistance and ease of soldering. Mounting shank is heavily knurled for secure mounting into terminal boards.



2. ***New Ceramic Stand-Off***

The body of this stand-off is made of JAN-1-10-grade L-5 ceramic, silicone impregnated. This gives you a component with highly improved resistance to moisture and fungi, as well as higher dielectric properties. X Type has a 6-32 thread screw stud; Y Type has a rivet stud.

These and other *Guaranteed Components* are described at length in the new CTC #300 Catalog. Write for it today.



Custom or Standard
The Guaranteed
Components

CAMBRIDGE THERMIONIC CORP.
456 Concord Ave., Cambridge 38, Mass.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 48A)

These instruments are designed for laboratory measurements and for monitoring both transmitter and antenna performance.

A single meter reads incident power, reflected power, net power to load, and SWR of the load. A selector switch connects the meter to read any of these quantities.

The MM400 series "MicroMatch" may be used with $1\frac{5}{8}$" or $\frac{7}{8}$" air line, and with RG-17/U and RG-8/U coaxial cable. Full-scale power ranges of 400, 1,200, and 4,000 watts are available.

Electrical Mismatch in TV Receiver Installations Diminished

An aid in the elimination of electrical mismatch existing between antenna and receiver in nearly all television receiver installations is made possible by a device described as "Telematch," according to its manufacturer, **Standard Transformer Corp.,** 3580 Elston Ave., Chicago 18, Ill.

Correction of line mismatch enables the full broadcast signal picked up by the antenna to be delivered, with minimum loss, to the receiver for improved reception. This often permits satisfactory reception with an inexpensive indoor antenna.

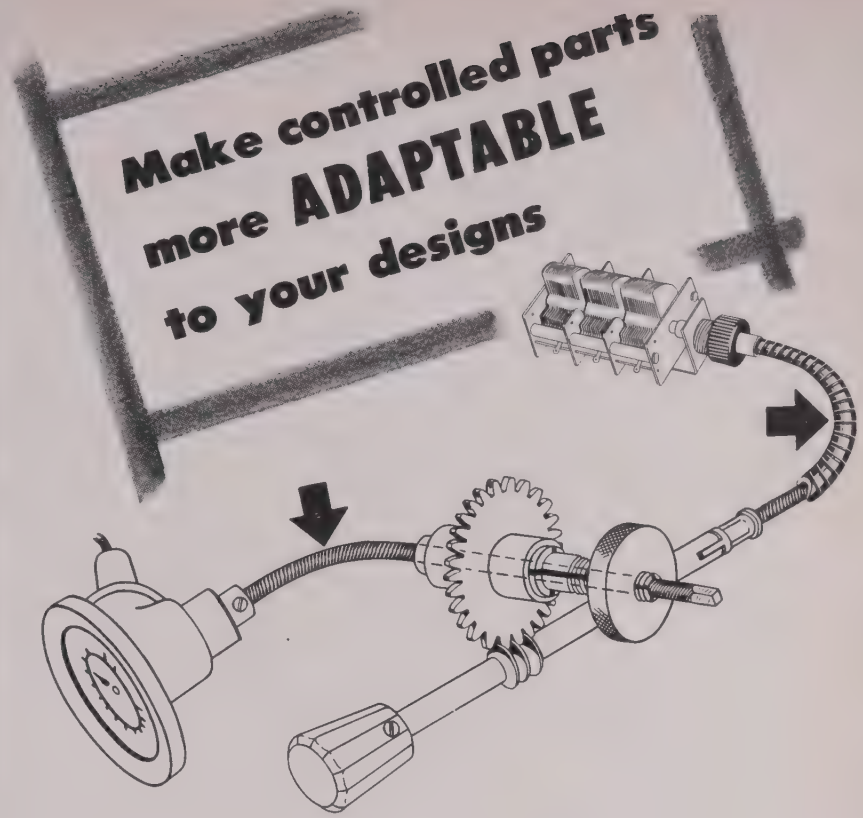
The "Telematch" has no tubes, and is installed by attaching two cable lugs to the receiver antenna input terminals.

Literature will be mailed on request.

Recent Calalogs

• • •Engineering Bulletin 4, describing the complete line of audio attenuators, fixed pads, special attenuator networks, and other communications equipment components, will be sent by **Shallcross Mfg. Co.,** 520 Pusey Ave,. Collingdale, Pa. to interested manufacturers on request.

(Continued on page 56A)



Adaptability is a prime advantage you gain by using S.S.White flexible shafts to couple variable elements to their control knobs or dials.

The example above shows why. The flexible shaft coupling permits you to position both the condenser and its control knob independently of each other. Likewise, the flexible shaft that transmits the movement of the tuning control shaft through a worm gear to the indicating dial makes it possible to place the dial where desired.

This *adaptability* of parts provided by S.S.White flexible shafts greatly simplifies the problem of satisfying such design requirements as circuit efficiency, easy assembly, wiring and servicing.

S.S.White remote control flexible shafts come in a wide range of sizes and characteristics and can be supplied in any required length. Specially designed for remote control, they are positive, sensitive and jump-free in operation.

S.S.White MAKES IT RIGHT

GET DETAILS IN THIS FLEXIBLE SHAFT HANDBOOK

You can get a free copy of this informative 260-page book on flexible shaft application and selection by writing to us on your business letterhead and mentioning your position.

S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO.
DEPT. G 10 EAST 40th ST., NEW YORK 16, N. Y.
FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

The continued expansion of the

NATIONAL UNION RESEARCH DIVISION

has created many fine positions for men interested in

VACUUM TUBE RESEARCH

Our laboratories are devoted entirely to research and development work on vacuum tubes. These include cathode ray, microwave, receiving, radial beam, subminiatures, and various special tube types. We are in a position to offer an interesting job, a stable future, and ideal working conditions to men who are qualified. Men with vacuum tube or similar experience and with degrees in Physics or Engineering are needed at the present time. Recent graduates without experience but with degrees in Physics or Electrical Engineering, as well as tube or circuit technicians, are invited to apply.

Before you decide on your future connection, be sure to look into the opportunities National Union has to offer.

Send resume to: Divisional Personnel Manager
National Union Research Division
350 Scotland Road
Orange, New Jersey

Radio and Radar Development and Design Engineers

Openings for experienced men at

HAZELTINE ELECTRONICS CORPORATION

Little Neck, L.I., N.Y.

Please furnish complete resume of experience with salary expected to:
Director of Engineering Personnel

(All inquiries treated confidentially)

ENGINEERS – ELECTRONIC

Senior and Junior, outstanding opportunity, progressive company. Forward complete résumés giving education, experience and salary requirements to

Personnel Department

MELPAR, INC.

452 Swann Avenue

Alexandria, Virginia

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

ENGINEERS

Location, Phoenix, Arizona. Excellent working conditions. Housing available. Motorola, Inc. announces a Research Laboratory devoted to armed service contract and company research in microwave, mobile communications, supervisory control, telemetering, miniaturization, and aviation electronics. Only fully qualified experienced inventors, engineers and scientists should apply. Send detailed statement of education and experience to Motorola Inc., D. E. Noble, 4545 Augusta Blvd., Chicago 51, Ill.

SENIOR AND JUNIOR ENGINEERS

Senior and junior engineers needed with experience on SCR-548 radar or similar equipment. Location about 50 miles from Los Angeles. Electronic Engineering Co., 2008 W. 7th Street, Los Angeles 5, Calif.

ELECTRONICS ENGINEER

Radio and industrial electronics in-instructor for two year technical college-Extension Division of Georgia Institute of Technology, Atlanta, Georgia. Write The Technical Institute, Chamblee, Georgia.

ENGINEERS

Men needed immediately for permanent positions on an experimental, development, and production program of complex electronic and electro-mechanical equipment. Work covers computers, servos, amplifiers, instrumentation, small mechanisms in aircraft simulation for complex training equipment. Applicants must have college degree, equivalent experience or both. Apply Personnel Mgr. Link Aviation, Binghampton, N.Y.

ELECTRO-ACOUSTIC ENGINEER

An attractive opportunity for an experienced engineer with thorough electro-acoustic training (transducers) in a small, sound rapidly growing concern. Permanent position with future opportunity as a research director. Write giving full details to Box 563.

RESEARCH SCIENTISTS

Experienced research scientists with advanced degrees and experience in physics, aerodynamics, electronics, optics, mathematics, chemistry, metallurgy, or meteorology to perform supervisory research and act as permanent consulting group to engineering laboratories. Excellent opportunity for men with right qualifications. Salary $8,000-$14,000 bracket. Write Box 564.

DEVELOPMENT ENGINEER

Newly formed and rapidly expanding aeronautical instrument company located in New York Metropolitan area is seeking an instrument development engineer

(Continued on page 51A)

Electronic Engineers

BENDIX RADIO DIVISION
Baltimore, Maryland
manufacturer of
RADIO AND RADAR EQUIPMENT
requires:

PROJECT ENGINEERS
Five or more years experience in the design and development, for production, of major components in radio and radar equipment.

ASSISTANT PROJECT ENGINEERS
Two or more years experience in the development, for production, of components in radio and radar equipment. Capable of designing components under supervision of project engineer.

Well equipped laboratories in modern radio plant . . . Excellent opportunity . . . advancement on individual merit.

Baltimore Has Adequate Housing

Arrangements will be made to contact personally all applicants who submit satisfactory resumes. Send resume to Mr. John Siena:

BENDIX RADIO DIVISION
BENDIX AVIATION CORPORATION
Baltimore 4, Maryland

WANTED:
CAREER MEN IN ELECTRONICS
at
RCA VICTOR
Camden, New Jersey

● Unlimited laboratory resources and facilities are waiting for top-flight men ready to assume responsibilities in handling and administering advanced projects in virtually every phase of electronics —infra-red, ultrasonic, audio and acoustic equipment; television receivers, antennas, radar, mobile communications; aviation communications and navigational aids in our Engineering Products and Home Instruments Departments at Camden, New Jersey.

These Openings Represent a permanent expansion in RCA Victor design and development activities at Camden, providing careers for men of high calibre with appropriate training and experience.

If You meet these Specifications, and if you are looking for a career which will open wide the door to the complete expression of your talents in the fields of electronics, write, giving full details, to:

ARNOLD K. WEBER,
Personnel Manager, Camden Plant
Box 133, RCA Victor Division
Radio Corporation of America
Camden, New Jersey

POSITIONS OPEN

(Continued from page 50A)

who is an electronics and servomechanism specialist to become Chief Engineer. Background must be well balanced in all phases of aeronautical instrument business, including laboratory and shop practice from first hand experience. Interesting salary and bonus. Box 565.

LABORATORY TECHNICIAN

Excellent opportunity for experienced electronics laboratory technician having experience in aircraft instruments and allied fields. Location Metropolitan New York. Experience and ability in all phases of laboratory testing and shop work desired. Salary commensurate with ability. Box 566.

COMMUNICATIONS ENGINEERS

Graduate communication engineers, Canadians citizens, interested in audio, radio and video frequency systems engineering. Salaries up to $350.00 per month depending on qualifications. Location, Montreal, Canada. Box 567.

TELEVISION ENGINEERS

Due to wide expansion in television program of long established radio and television manufacturing company, positions are now available for engineers with 3 or more years television experience. Excellent working conditions in modern, well-equipped laboratory. Company located in northwest portion of New York State. Housing no serious problem. Salaries commensurate with ability. Box 568.

SCIENTISTS AND ENGINEERS

Wanted for interesting and professionally challenging research and advanced development in the fields of microwaves, radar, gyroscopes, servomechanisms, instrumentation, computers and general electronics. Scientific or engineering degrees or extensive technical experience required. Salary commensurate with experience and ability. Direct inquiries to Mgr., Engineering Personnel, Bell Aircraft Corp. P.O. Box 1, Buffalo 5, N.Y.

ENGINEERS

An unusual opportunity exists for qualified engineers to participate in the growth of the industrial television field. Experience in video, pulse, electronic display and circuit techniques with good educational background required. Openings range from Junior to Project Engineers. Write to: Leonard Mautner, Vice-President, Television Equipment Corp., 238 William St., New York 7, N.Y.

RADIO ENGINEERS

Outstanding opportunity with progressive, rapidly growing company for radio engineers experienced in high frequency work. An interesting, attractive future assured, but requirements of jobs must be paralleled by necessary skill. If you have a background of high frequency work, tell us about yourself in résumé giving education, experience and salary requirements. Plant located in New Jersey within commuting distance of New York City. Box 569.

(Continued on page 52A)

WANTED PHYSICISTS ENGINEERS

Engineering laboratory of precision instrument manufacturer has interesting opportunities for graduate engineers with research, design and/or development experience on radio communication systems, Servomechanisms (closed loop), electronic & mechanical aeronautical navigation instruments and ultra-high frequency & microwave technique.

WRITE FULL DETAILS
TO
EMPLOYMENT SECTION

SPERRY GYROSCOPE
COMPANY
DIVISION OF SPERRY CORP.
Marcus Ave. & Lakeville Rd.
Lake Success, L.I.

TEC
ENGINEERS

TELEVISION EQUIPMENT CORPORATION offers an unusual opportunity for qualified engineers to participate in the growth of the rapidly expanding Industrial Television field.

Experience in video, pulse, electronic display and circuit techniques with good educational background required. Several positions are available ranging from junior to project engineers.

Compensation is commensurate with ability. Opportunity to participate in company profit sharing plan.

Apply by letter to Leonard Mautner, Vice President:

TELEVISION EQUIPMENT CORPORATION
238 William Street
New York 7, N.Y.

CHASSIS? BOXES? CABINETS?

Get them NOW

BUD Has Them For You!

When it comes to sheet metal equipment . . . BUD has your housing problem solved.

We, at BUD RADIO, INC., make 337 different sheet metal products and 290 of them are available for immediate delivery, at this time. That means that 86% of the cabinets, chassis, utility boxes, carrying cases, etc., are waiting to be shipped to satisfy your needs.

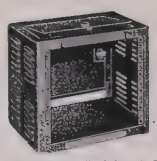
Don't wait until too late . . . get into the position of being able to satisfy your NEEDS now! Check your requirements, now, and order your needs in the sheet metal line.

See the complete BUD miniature sheet metal housing line for the right answer to your problems on small cabinet ware.

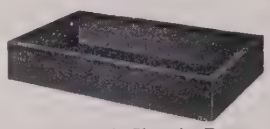
Remember that when comparisons are made on the basis of QUALITY, UTILITY AVAILABILITY AND PRICE: BUD leads all the rest. WE ARE PLEASED TO QUOTE ON YOUR REQUIREMENTS FOR SPECIAL SHEET METAL HOUSINGS.

BUY THE BEST . . . BUY BUD

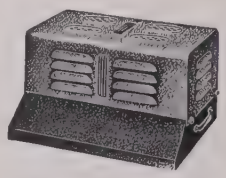
Write for Catalog



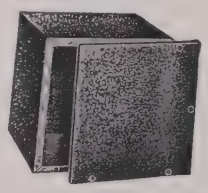
BUD DeLuxe Cabinet Racks



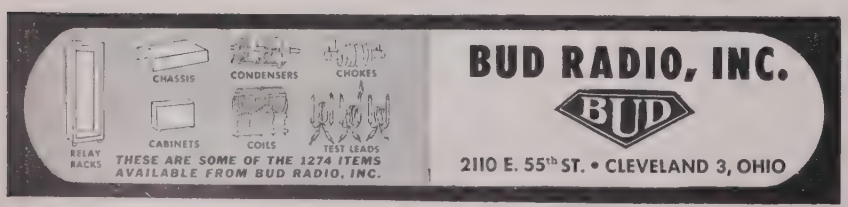
BUD Steel Chassis Bases



BUD Sloping panel Amplifier Foundations



BUD Metal Utility Cabinets



RESEARCH OPPORTUNITIES AT WESTINGHOUSE IN TELEVISION

Physicists and electronic engineers needed for an extensive project at the Westinghouse Research Laboratories in Pittsburgh. Excellent opportunities for specialists in electron-optical devices, optics, systems and circuits.

For application write Manager, Technical Employment Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh, Pa.

POSITIONS OPEN

(Continued from page 51A)

DEVELOPMENT ENGINEER
DESIGN ENGINEER

Development Engineer with at least 5 years experience in developing electronic equipment in the 100 to 1,000 megacycle range.

Design Engineer with at least 5 years experience with electro-mechanical design problems where space and difficult service conditions are important. Ideal laboratory conditions. 5 day week, paid vacation, paid medical and surgical policy, paid hospitalization policy and paid life insurance. Located in New Jersey. Box 570.

DESIGN ENGINEER

Design Engineer on R.F. Transmission lines and fittings. Some experience also on microwave equipment. Box 571.

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants, and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

RADIO PHYSICIST

B.Sc. May 1949, radio physics option of honor mathematics and physics, University of Western Ontario. 3 years radar in Canadian Navy. Age 27, married. Desires development, research or interesting position with good future. Box 243W.

ELECTRONIC ENGINEER

B.S.E.E. June 1949, University of Cincinnati, age 30. Experience 2½ years co-op in development and test components, video and I.F. amplifiers, servo-mechanisms, instrument landing systems. Working knowledge of machine tools and machine shop practice. Desires position in research or development. Member of Eta Kappa Nu. Box 244W.

ENGINEER

B.A.,Sc., E.E., April 1949, U.B.C.; age 27, married; appreciable experience as technician in F.M. and microwave radio relay, audio, mobile and harbour control F.M. with some design and development. Desires development or research engineering. Preference microwave. D. Nuttall, 2870 W. 13, Vancouver, B.C., Canada.

(Continued on page 53A)

REGULATED
POWER SUPPLIES

DESIGNED for use in industry, school and laboratory these power supplies are ruggedly constructed and conservatively rated for long and dependable service. Attractively styled and priced, these units have found wide acceptance. They are also available in complete kit form for maximum economy. The following characteristics apply to the models listed below:

CHARACTERISTICS

INPUT: 105-125V/50-60cps/100 watts.

OUTPUT: Variable from 200 to 325VDC @ 100ma. regulated, 6.3VAC CT @ 3A unregulated.

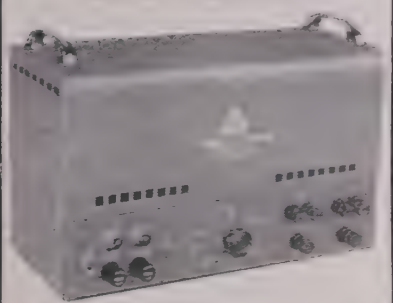
REGULATION: Less than 1% no load to full load. Less than 1% for line voltage variation 105 to 125 volts.

NOISE AND RIPPLE OUTPUT: Less than 10 mv rms for above ratings.

TUBE COMPLEMENT: 5V4G, VR-105, 6SH7, 2-6Y6G.

DC OUTPUT CONNECTIONS: Either positive or negative may be grounded.

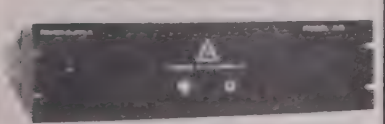
BENCH MODEL 25



COMPACT AND LIGHT WEIGHT. Functionally designed for maximum convenience in operation. Six sturdy, insulated, "5-way" output terminal posts. Grey finish. 14" wide, 6" deep, 8" high. Weight 17 pounds.

Model 25. Factory assembled and wired . $39.95
Model 25K. Complete kit $29.95
(f.o.b. Corona, N.Y.)

RACK MOUNTING MODEL 28



COMPACT UNIT FOR STANDARD RACK MOUNTING. Rear access terminal board. Panel 19" x 5¼". Black wrinkle finish (grey optional). Depth behind panel 7⅛". Weight 16 pounds

Model 28. Factory assembled and wired ..$34.95
Model 28K. Complete kit $24.95
(f.o.b. Corona, N.Y.)

BASIC REGULATED POWER SUPPLY KIT MODEL 31K

Basic kit of parts for incorporation into equipment comprises cased power transformer and filter choke, oil-filled capacitors, sockets, resistors, tubes and schematic diagram.

BASIC KIT 31K $14.95
(f.o.b. Corona, N.Y.

LAMBDA
ELECTRONICS CORP.
103-02 NORTHERN BLVD.
DEPT. RE CORONA NEW YORK

Positions Wanted

(Continued from page 52A)

ENGINEER

Interested in television and its industrial application. Columbia University 1949, M.S. in I.E. City College 1948, B.S. in E.E. Engineer in training, State of New York. Prefers position in New York area. Box 245W.

ELECTRONIC ENGINEER

B.E.E., February 1949, Cornell University. Age 24. Air Corps electronics officer, training at M.I.T., Harvard, Yale. Experience in electronics and power work. Interested in industrial electronics field. Box 246W.

JUNIOR ENGINEER

Graduate R.C.A. Institutes; age 30; married. 3 years electrical engineering major in electronics, continuing studies for B.E.E. at night. Desires work as Junior Engineer in design and development of communication equipment under Senior Engineer. 4 years radio servicing experience preceding 3½ years U. S. Army radio servicing. 1st class Radiotelephone, 2nd class Radiotelegraph, and Class B amateur F.C.C. Licenses. Box 247W.

ELECTRONIC ENGINEER

B.S. in E.E. 1948 University of Illinois. Experience with reputable firm in circuit design. Desires position anywhere in the U.S. Box 248 W.

ASSISTANT CHIEF ENGINEER

Radio-Television

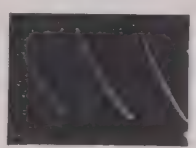
Excellent opportunity for an administrative engineer with engineering degree and at least 10 years' commercial design experience in radio receiver, television field. Must have sense of responsibility. Write, stating age, education, experience, salary expected, to Freed Radio Corporation, 200 Hudson Street, New York 13, N.Y.

***In only* 1 SECOND!**

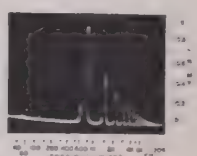
COMPLETE AUDIO WAVEFORM ANALYSIS

with the

AP-1 PANORAMIC SONIC ANALYZER



Oscillograph of waveform to be analyzed



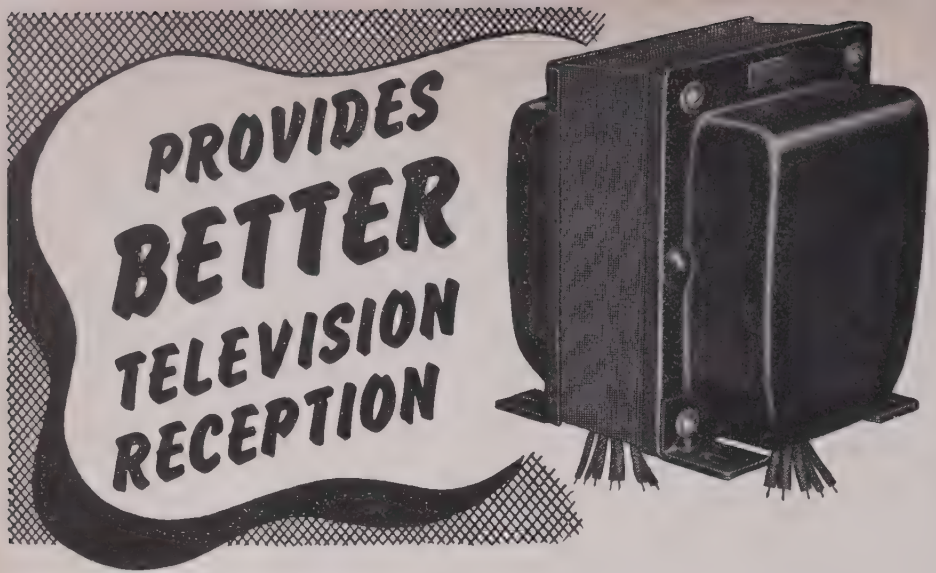
Panoramic Sonic Analysis of the same wave

Provides the very utmost in *speed, simplicity* and *directness* of complex waveform analysis. In only one second the AP-1 *automatically* separates and measures the frequency and amplitude of wave components between 40 and 20,000 cps. Optimum frequency resolution is maintained throughout the entire frequency range. Measures components down to 0.1%.

- **Direct Reading**
- **Logarithmic Frequency Scale**
- **Linear and Two Decade Log Voltage Scales**
- **Input voltage range 10,000,000:1**

AP-1 is THE answer for practical investigations of waveforms which vary in a random manner or while operating or design constants are changed. If your problem is measurement of harmonics, high frequency vibration, noise, intermodulation, acoustics or other sonic phenomena, investigate the overall advantages offered by AP-1.

Write NOW for complete specifications, price and delivery.



Small, but important features of design and construction make Acme Electric Transformers better performers. For example, cores are riveted as well as bolted, and varnish impregnated to positively eliminate any "hum or buzz." Acme Electric engineers can design a Power Transformer, Filter Reactor, Vertical Sweep Output Transformer, to your exact requirement, from standard parts and assemblies to provide better performance for your set.

The 500 V. A. Acme Electric Television Power transformer, may be the solution to your problem of better set performance.

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Acme ACME Electric
TRANSFORMERS

To Lower Your Production Costs

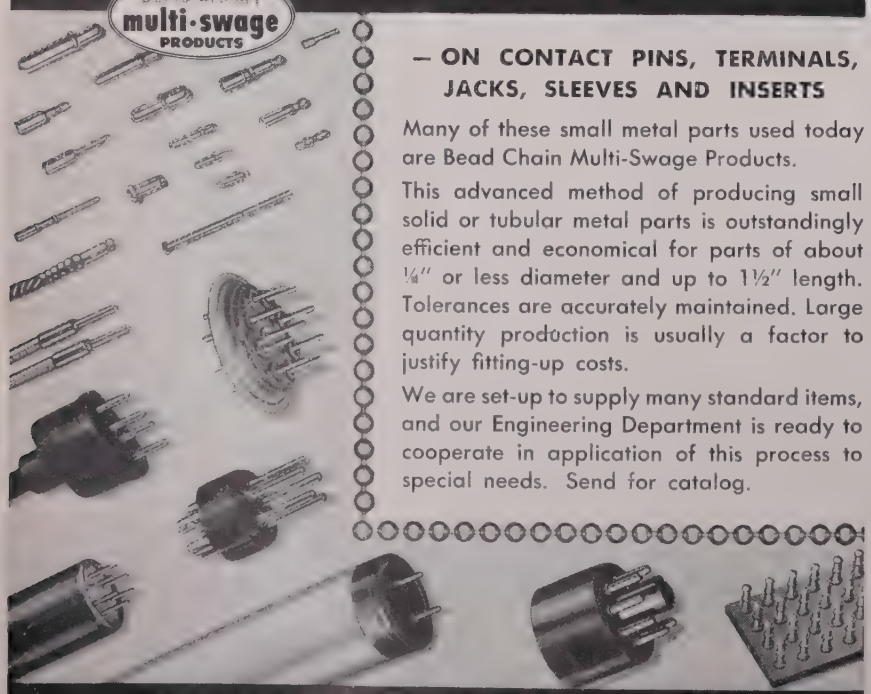
BEAD CHAIN multi-swage PRODUCTS

— ON CONTACT PINS, TERMINALS, JACKS, SLEEVES AND INSERTS

Many of these small metal parts used today are Bead Chain Multi-Swage Products.

This advanced method of producing small solid or tubular metal parts is outstandingly efficient and economical for parts of about ¼" or less diameter and up to 1½" length. Tolerances are accurately maintained. Large quantity production is usually a factor to justify fitting-up costs.

We are set-up to supply many standard items, and our Engineering Department is ready to cooperate in application of this process to special needs. Send for catalog.



THE BEAD CHAIN MANUFACTURING CO.
60 Mountain Grove St., Bridgeport, Conn.

Positions Wanted

(Continued from page 53A)

ELECTRONIC ENGINEER

B.S.E.E. June 1949, Polytechnic Institute of Brooklyn. Single. 2 years experience as Navy electronic technician. Member Tau Beta Pi, Eta Kappa Nu. Desires position in electronic field; metropolitan area preferred. Box 265 W.

FIELD SALES ENGINEER

B.S.E.E. communications major. 5 years experience in microwave, radar, and general communication equipment. Also some aircraft and electronic control experience. Finest references. Box 266 W.

COMMUNICATIONS ENGINEER

B.S.E.E. June 1949, University of Minnesota, communications major. Age 25. Married, no children. 2 years experience GCA and other radar, 2 years airline radio and telephone work. Desires position with future in TV or electronics. Box 267 W.

ELECTRONIC ENGINEER

Development or research in electronic control, instruments, or power preferred by ambitious veteran. Age 23. Married. M.S.E.E. June 1949. Tau Beta Pi, Sigma Pi Sigma member. 2 years varied industrial experience. Private pilot's license. Box 268 W.

TELEVISION ENGINEER

Graduated American Television Institute of Technology with B.S.T.E. Age 22. Single. Desires position in design and development work in vicinity of Boston, Mass. Box 269 W.

ENGINEER

June 1949 honor graduate of leading midwest engineering college B.S.E.E. Harvard-M.I.T. radar course. 3 years experience as research and development officer. MOS 7050. Experience with electronic bombing computers and telephone subs. equipment. Tau Beta Pi, Eta Kappa Nu—President, Student AIEE. Prefer connection with quality conscious firm in southwest U.S.A. Box 270 W.

ELECTRONIC ENGINEER

Ex-flying officer. Industrial engineering and electronic engineering background. Both research and development and manufacturing experience on airborne radar, television and guidance systems. Schools—NCE, University of Dayton, Harvard, Columbia and M.I.T. Box 271 W.

TELEVISION ENGINEER

Graduated American Television Institute of Technology January 1949 with B.S.T.E. Age 23. 1st Class FCC license. 2 years Army radio operator mechanic. Desires position as development or TV station engineer. Thorough understanding of RCA and Dumont TV equipment. Box 272 W.

ADMINISTRATIVE OR EXECUTIVE

Retired Naval officer. M.S. Radio Engineering; Harvard 1928. Varied experience in charge reorganizing and operating

(Continued on page 55A)

Positions Wanted

(Continued from page 54A)

major units Naval Communication System, radio procurement, electronics planning, radio stations maintenance, etc. Desires position as administrator or executive in communications, radio, or electronics, anywhere in U. S. Available immediately. Box 273W.

JUNIOR ENGINEER

B.S. Radio Engineer, Chicago Technical College; Member Sigma Phi Delta, March 1949. Age 23; single. Navy experience Electrical Maintenance Technician. Desires position with a good opportunity. Box 274W.

ENGINEER

M.S.E.E., June 1949, California Institute of Technology; age 23; married. Two years Navy radio technician. Summer work in small motor design. Member Tau Beta Pi. Desires work in control or telemetering. Box 275W.

ELECTRONIC ENGINEER

B.E.E., New York University 1948, electronics major. One year GE test experience. GE advanced course in engineering. Interested electronic control equipment, servo-mechanisms; computers. New York Metropolitan area. Box 276W.

ENGINEER

B.E.E., June 1949. Cooper Union. Age 28. Married. Three years electrical testing and inspection experience including supervision. Three years Army Signal Corps as radio serviceman. Desires position with future. Box 277W.

EXECUTIVE ASSISTANT

Business administration plus engineering training. M.B.A., University of Chicago; B.S.E.E., B.S. (math.), University of Michigan. Eta Kappa Nu. Single. Age 26. Signal Corps technician; 1 year research, production quality control experience. Desires job in medium size concern. Résumé upon request. Box 278W.

ENGINEER

B.S.E.E., September 1949, University of Florida. Age 30. Married. Two years Navy radio-radar technician and school. One year Chief Engineer 250 watt radio station. Motor and power transformer experience. Interested sales or construction. Will travel anywhere. Box 279W.

SALES ENGINEER OR EXECUTIVE ASSISTANT

Former assistant to Vice President of a world-wide export organization invites inquiries from firms having need for addition to sales engineering staff or assistant to top executive. Young, energetic, widely traveled with a solid background of research design and supervision in all phases of electrical and electronic equipment. Capable of handling sales, engineering, production and personnel. Box 281W.

(Continued on page 56A)

Call on Berkeley's engineering and manufacturing facilities for your specialized applications.

high Speed

COUNTING UNITS FOR COUNTING, TIMING, FREQUENCY MEASUREMENT APPLICATIONS

The New

Berkeley

DECIMAL COUNTING UNIT

is a scale-of-ten, high speed counting component with unlimited possibilities in counting, scaling and timing applications. Compact construction—reliable circuit—direct numerical indication. Ready for plug-in operation. Convenient power and pulse input requirements.

Write for Bulletin DCU-116 for full specifications

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FM SIGNAL GENERATOR

MODEL 202-B

FREQUENCY RANGE 54 to 216 MEGACYCLES

The model 202-B is specifically designed to meet the needs of television and FM engineers working in the frequency range from 54-216 mc. Following are some of the outstanding features of this instrument:

RF RANGES — 54-108, 108-216 mc. ±0.5% accuracy. Also covers 0.1 mc. to 25 mc. with accessory 203-B Univerter.

VERNIER DIAL — 24:1 gear ratio with main frequency dial.

FREQUENCY DEVIATION RANGES — 0-24 kc., 0-80 kc., 0-240 kc.

AMPLITUDE MODULATION — Continuously variable 0-50%; calibrated at 30% and 50% points.

MODULATING OSCILLATOR—Eight internal modulating frequencies from 50 cycles to 15 kc. Available for FM or AM.

RF OUTPUT VOLTAGE — 0.2 volt to 0.1 microvolt. Output impedance 26.5 ohms.

FM DISTORTION—Less than 2% at 75 kc deviation.

SPURIOUS RF OUTPUT—All spurious RF voltages 30 db or more below fundamental.

Write for Catalog F

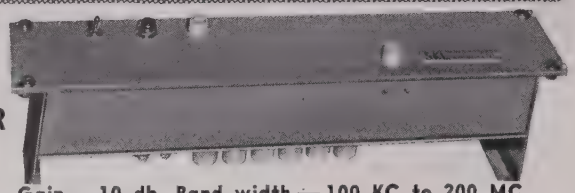
BOONTON RADIO Corporation

BOONTON, N. J., U. S. A.

DESIGNERS AND MANUFACTURERS OF THE Q METER - QX CHECKER FREQUENCY MODULATED SIGNAL GENERATOR BEAT FREQUENCY GENERATOR AND OTHER DIRECT READING INSTRUMENTS

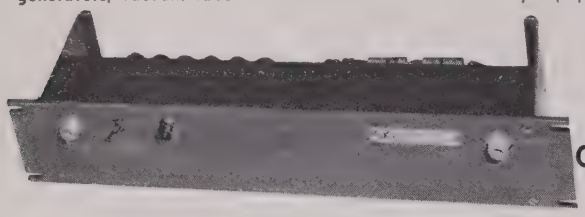
SKL 200 MC BAND WIDTH AMPLIFIERS

MODEL 200A
WIDE BAND
CHAIN AMPLIFIER



Impedance — 200 ohms. Gain — 10 db. Band width — 100 KC to 200 MC. Response — ± 1 db. Standing Wave Ratio — Less than 1 db.

Using a chain of six 6AK5 tubes the single stage Model 200A uses delay line coupling in the grid and plate circuits. Due to its low impedance existing coaxial cables can be used. Due to its wide band width it is invaluable as an aperiodic preamplifier for signal generators, sweep generators, vacuum tube voltmeters and other laboratory equipment.



MODEL 202
WIDE BAND
CHAIN AMPLIFIER

Band width — 100 KC to 200 MC. Gain — 20 db. Response — ± 1.5 db. Impedance — 200 ohms. Standing wave ratio — Less than 1.5 db.

The dual stage, Model 202 has substantially linear phase shift owing to mutual inductance coupling in the delay lines. With its wide pass band and very short rise time this amplifier offers unique advantages in the study of pulse and transient wave forms in nuclear research, oscillography and television testing.

SKL SPENCER KENNEDY LABORATORIES, INC.
186 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS.

Pioneer in Radio Engineering Instruction Since 1927

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The "NOBLELOY" X Type Resistors has proven itself over a period of 5 years in thousands of critical electronic circuits. Values and tolerances, ½ ohm to 30 megohms 1%; ½ ohm to 200,000 ohms, ⅛%. Sizes, ½ to 5 watt.

CONTINENTAL CARBON, INC. CLEVELAND 11, OHIO

Positions Wanted

(Continued from page 55A)

JUNIOR ENGINEER—PHYSICIST

Five and one-half years of physics, electrical engineering and electronics in Fordham, University of Rochester, Harvard, M.I.T. Three years Naval electronics officer; B.S. in physics, June 1949. Age 25; married; one child. Desires employment in electronic engineering, sales or development, anywhere, preferably west coast. Box 280W.

ELECTRONICS ENGINEER

Guided missile electronics engineer. Currently engaged in production engineering of guided missiles. Three years experience in development of guidance and control equipment. Four years radar development experience for Army. Graduate engineer with postgraduate school. Box 282W.

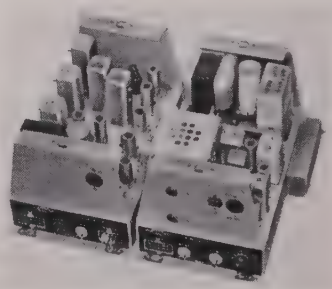
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 49A)

Radiotelephone Equipment Operates on Minimum Power

Completion of the first production run of their new mobile radiotelephone equipment for the 152- to 162-Mc communication band, has been reported by **Kaar Engineering Co.**, Middlefield Rd., Palo Alto, Calif.



The manufacturer claims that this new equipment features lower standby battery drain than previously has been possible with equipment of this type. The transmitter consumes no power from the battery during standby periods; the receiver uses but 4 amps. In combination, the equipment consumes a total of just 4 amps during standby operation, yet permits full performance.

This feature means that radiotelephone systems can now be used in many installations from which they have heretofore been barred because of the bulky power supply required.

The Kaar equipment used is the FM-47X receiver and FM-177X 15-watt, or FM 179X 50-watt transmitter.

Literature describing the equipment in detail may be obtained by writing to the manufacturer.

(Continued on page 57A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 56A)

Electronic Variable Speed Motor Control

A system for the stepless speed control of fractional hp motors has been developed by **Servo-Tek Products Co., Inc.** 4 Godwin Ave., Paterson 1, N. J.

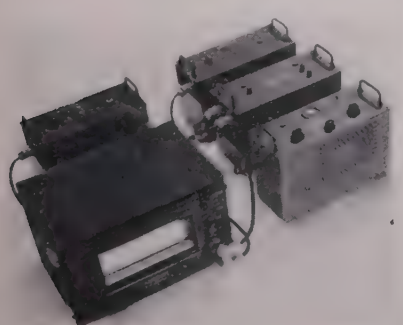
A simplified circuit is used which makes possible an economical electronic control system without sacrificing desirable operating features. Operating from a 110- or 220-volt 50–60 cps ac power source, the power unit utilizes full-wave gaseous rectification to supply the armature and the field of the ball bearing dc motor. The amount of voltage supplied to the armature is controlled by an electrical "brain" which reacts to change the applied voltage to correct for the slightest change in motor load, or by the operator.

The control unit, which may be remote, permits the use of any speed from 20 to 1,800 rpm standard.

Reversing control units are available, which incorporate features to achieve full speed reversals within 1 second.

Rectangular Co-ordinate Recorder

A new instrument, the AIL Type 373 Rectangular Co-ordinate Recording System, which provides, in Cartesian co-ordinates, an inked plot voltage, or of the logarithm of voltage, as a function of the



displacement angle of a measure element, has been developed by **Airborne Instruments Laboratory, Inc.**, 160 Old Country Road, Mineola, L. I., N. Y.

(Continued on page 58A)

ANNOUNCING! . . .

NEW SLIDE WIRE RESISTANCE BOXES!

Technology Instrument Corporation's newly developed Type 110 Slide Wire Resistance Boxes represent a big step forward in the design of specialized instruments for student and general laboratory use. A combination of high accuracy, wide resistance range and convenient size, the Type 110 is suitable for use at audio and super-sonic frequencies.

Its compactness combined with its low cost make it possible to provide more of these important instruments for college and industrial laboratories. Yet it is suitable for use in most cases where a more elaborate decade box is used.

The Type 110 Slide Wire Resistance Boxes consist of a precision non-inductive decade resistor and a continuously adjustable slide wire resistor which provide a useful, direct-reading resistance range ratio of 1000 to 1. Two models are now available: Type 110-A, with a range of 0-11,000 ohms; and Type 110-B, with a range of 0-110,000 ohms. Send a trial order today—or if you prefer, ask for detailed information.

SPECIFICATIONS

Accuracy—Decade resistance cards adjusted to within 0.1% of nominal values. Slide wire resistors direct-reading to within 1% ot maximum resistance.

Temperature Co-efficient—Slide wire and decade resistors have temperature co-efficient of less than 0.00002 part per degree C. at room temperature.

Mounting—Cast aluminum cabinet, aluminum panel. All resistance elements and switches completely enclosed. Dimensions: 4" wide, 8⅝" long. 5⅜" high. Net weight, 4 lbs.

PRICES

Type 110-A: 0-11,000 ohms, 2 dials $42.50
Type 110-B: 0-110,000 ohms, 2 dials $45.00

TECHNOLOGY INSTRUMENT CORP.
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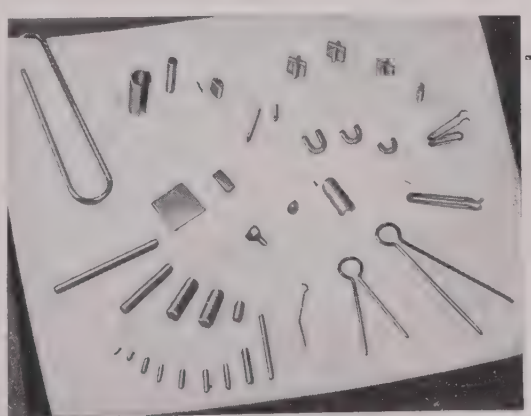
Rochester, N.Y.—Charlotte 3193-J Dallas, Tex.—Logan 6-5097



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PRECIOUS METALS
FOR
ELECTRICAL CONTACTS ON POTENTIOMETERS, SLIP RINGS, RELAYS AND SWITCHES

PALINEY #7
SLIDING CONTACTS FOR POTENTIOMETERS

PALINEY #7 is being used for a contact material on potentiometers wound with a nickel-chrome alloy resistance wire. This combination is consistently producing units with life of better than one million cycles and maintained accuracy of 0.1% or better throughout the life of the unit.

NEY-ORO #28
SLIP RING BRUSHES

NEY-ORO #28 is a special alloy developed as a contact brush material for uses against coin silver slip rings. Laboratory tests and reports from users indicate life of better than 10 million revolutions with no electrical noise.

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TWO NEW
TWIN POWER SUPPLIES

MODEL 610-F

- Precise Electronic Regulation.
- 2 Independent Sources of Power.
- 0-325 V.D.C. at 0-60 Milliamperes. Continuously Adjustable.
- 0-325 V.D.C. at 0-120 Mils if the 2 Sources are Combined.
- Both D.C. Outputs Metered for Voltage or Current.
- 6.3 and 12.6 V.A.C. Outputs Provided.
- A.C. Ripple Less than 10 Millivolts.

MODEL 1210

- Precise Electronic Regulation.
- 2 Independent Sources of Power.
- 0-500 V.D.C. at 0-150 Milliamperes. Continuously Adjustable.
- 0-500 V.D.C. at 0-300 Mils if the 2 Sources are Combined.
- Both D.C. Outputs Metered for Voltage or Current.
- 6.3 or 12.6 V.A.C Outputs Provided
- A.C. Ripple Less Than 10 Millivolts.

Furst Twin Power Supplies double the usefulness of a single unit at considerable saving in space and cost. Write for complete specifications on these and other Furst Twin Power Supply Models.

FURST ELECTRONICS

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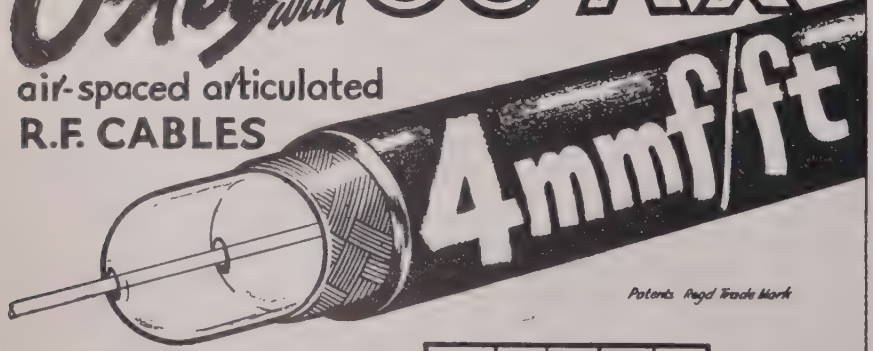
Only with CO-AX

air-spaced articulated R.F. CABLES

4mmf/ft



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IMMEDIATE DELIVERIES FOR U.S.A.

Billed in Dollars. Settlement by your check. Transaction as simple as any local buy.

LOW ATTEN TYPES	IMPED OHMS	ATTEN db/100ft at 100 Mc/s.	LOADING ft per Mf.	O.D."
A 1	74	1.7	0.11	0.36
A 2	74	1.3	0.24	0.44
A 34	73	0.6	1.5	0.88

HIGH POWER FLEXIBLE

LOW CAPAC TYPES	CAPAC mmf/ft.	IMPED OHMS	ATTEN db/100ft 400 Mc/s.	O.D."
C 1	7.3	150	2.5	0.36
PC 1	10.2	132	3.1	0.36
C 11	6.3	173	3.2	0.36
C 2	6.3	171	2.15	0.44
C 22	5.5	184	2.8	0.44
C 3	5.4	197	1.9	0.64
C 33	4.8	220	2.4	0.64
C 44	4.1	252	2.1	1.03

PHOTOCELL CABLE

V.L.C. ★

★ Very Low Capacitance cable

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CABLES: TRANSRAD, LONDON.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

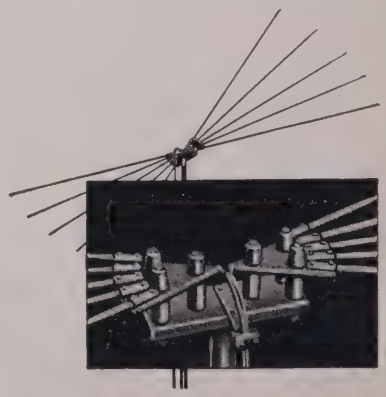
(Continued from page 57A)

Usable chart width is 10″, corresponding to a voltage range of 10,000 to 1, or 80 db. Both pen and paper feed are servo-controlled, with chronograph paper feed optional. Maximum pen speed is 40″ per second, equivalent to 320 db per second. At full scale expansion, the maximum paper feed rate is 10″ per second.

The system finds application whenever it is desired to record voltage as a function of time or an angle. It can be used for recording light intensities, sound pressures, and heat levels at writing rates higher than formerly available. As originally designed to plot logarithmically the field-strength pattern of narrow-beam radar antennas, the system consists of a selective amplifier, pen and paper servo amplifiers, a power supply, and the recorder. The system operates from 115 volts, 60 cps power supply, and can be supplied in either portable carrying cases, or in standard rack and panel construction.

Di-Fan Antenna for TV and FM

The new type 710 Di-Fan is a broadband receiving antenna tuned to receive all television and FM channels, according to the manufacturer, **Andrew Corp.**, 421 Seventh Ave., New York 1, N. Y.



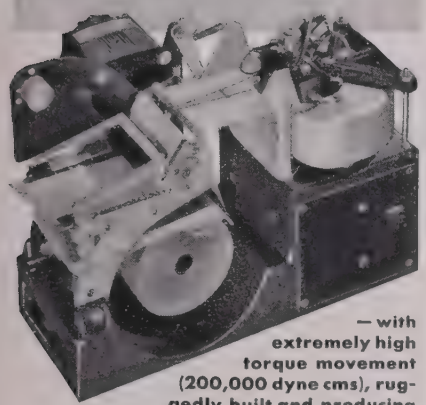
The horizontal directivity pattern of the Di-Fan in TV channels 2 through 6 and in the FM band is a figure eight, broadside to the major axis of the antenna. In the high-frequency TV channels 7 through 13, the forward gain is decreased somewhat while the angle of acceptance is enlarged.

It is claimed that the antenna maintains the standard 300-ohm impedance over the TV spectrum; provides ghost-free reception from every TV station within range; and shows little mismatch loss over a wide range of frequencies. The fan elements are constructed of high-strength aluminum alloy with supports of plated steel.

For complete information contact J. F. White at Andrew.

(Continued on page 59A)

INKLESS
RECTILINEAR
Direct Writing
RECORDERS



—with extremely high torque movement (200,000 dyne cms), ruggedly built and producing clear, *permanent* records.

Sanborn Direct Writing Recorders offer these advantages, plus performance characteristics (see table below) that make them outstandingly useful in a wide variety of industrial recording applications.

Whenever a phenomenon or action lends itself to transformation to an electrical quantity, and whether the variation is steady or of a pulse type, these Recorders (with associated amplifiers) can be used for immediate, direct, continuous registration.

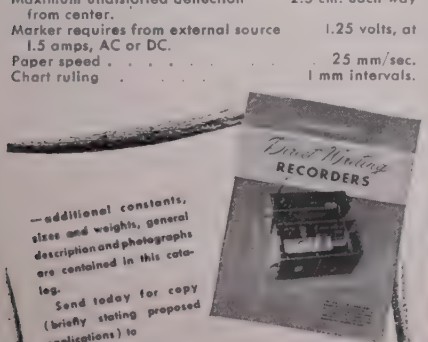
Typical applications, actual and potential, include: temperature changes, automotive noise and vibration, varied output of strain gages and bridges, lightning and earthquake recording, pressure variations, audio frequency response, and many others.

Recording paper (Sanborn Permapaper) is heat sensitive—*eliminating* ink—yet clear and *permanent*. Trace is rectilinear—no curvature, no negative time intervals—yet with totally negligible tangent error.

Sanborn Recorders are available in self-contained, portable recording outfits, complete with cases and controls, or in component form for integration with existing equipment. *Associated amplifiers are also available.*

TABLE OF CONSTANTS

Sensitivity	10 ma I cm.
Coil resistance	3,000 ohms, center tapped for push-pull operation.
Critical damping resistance	500 ohms.
Undamped fundamental frequency	45 cycles/sec.
Stylus heater requires from external source	1.25 volts, 3.5 amps, AC or DC.
Maximum undistorted deflection from center.	2.5 cm. each way
Marker requires from external source	1.25 volts, at 1.5 amps, AC or DC.
Paper speed	25 mm/sec.
Chart ruling	1 mm intervals.



—additional constants, sizes and weights, general description and photographs are contained in this catalog.

Send today for copy (briefly stating proposed applications) to

INDUSTRIAL DIVISION
Sanborn Company
CAMBRIDGE 39, MASSACHUSETTS

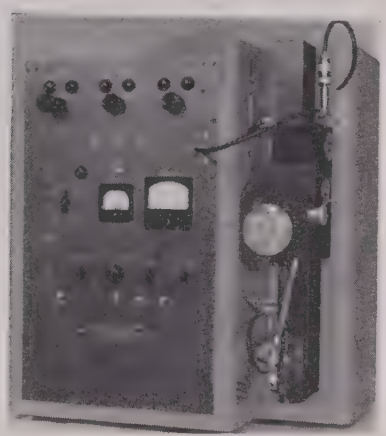
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 58A)

A Microwave Dielectrometer

A microwave dielectrometer is now available for measuring the dielectric constant and loss of a wide variety of materials at nominal frequencies of 1,000, 3,000 and 9,000 Mc from **Central Research Laboratories, Inc.,** Red Wing, Minn.



The instrument consists of a slotted waveguide, precision traveling probe, modulated klystron oscillators, probe output amplifier, and associated power supplies and equipment.

The sample to be measured is inserted ahead of a short-circuiting plug and the effect of this arrangement on the standing-wave pattern in the guide provides data for calculating the dielectric constant and loss of the material.

At 1,000 and 3,000 Mc, the wave guide is used as a coaxial line operating in the TEM mode, and at 9,000 Mc either as a circular pipe operating in the TE_{11} mode or as a coaxial line operating in the TE_{10} mode. Solids are measured directly in the wave guide in the form of cylindrical samples 1″ in diameter and about 1″ to 2″ long with a $\frac{3}{8}$″ hole coaxial with the outer surface except when the guide is operated as a circular pipe at 9000 Mc.

Recent Catalogs

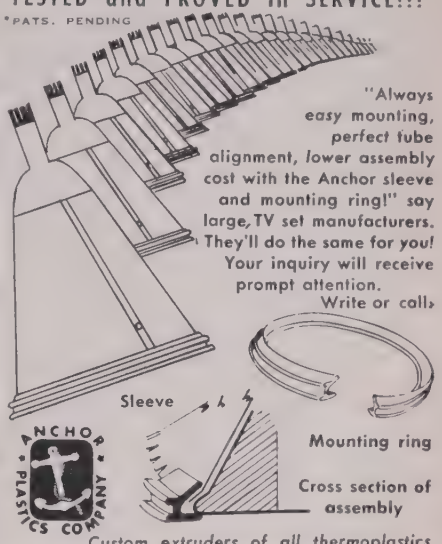
• • • Publication of the new Stancor catalog has been announced by **Standard Transformer Corp.,** 3580 Elston Ave., Chicago 18, Ill. This information will cover electrical and physical specifications, including list prices, of more than 400 items. Listings of transmitting and rectifier tubes, driver-modulator combinations, matched power supplies, output transformer-tube combinations, and detailed dimensional drawings of all Stancor transformer mounting styles are included. Requests for copies should be directed to G. C. Knoblock, Advertising Manager.

(Continued on page 60A)

***Successes:* 25,000!**
***Failures:* None!**

Anchor Plastics' sleeve* and mounting ring* for 16″ metal TV tubes—TESTED and PROVED in SERVICE!!!

*PATS. PENDING



"Always easy mounting, perfect tube alignment, lower assembly cost with the Anchor sleeve and mounting ring!" say large TV set manufacturers. They'll do the same for you! Your inquiry will receive prompt attention. Write or call›

ANCHOR PLASTICS COMPANY

Custom extruders of all thermoplastics.

ANCHOR PLASTICS CO., Inc.
533-541 Canal St., New York 13, N. Y.
Telephone: Digby 9-1242

Easy Accessibility!

JOHNSON 147-800 SERIES
WITH DETACHABLE SOCKETS

This popular series permits bulb installation from front—or from rear by means of a detachable spring bracket. Jewel is 1″ diameter in friction type holder with polished chrome bezel. Available in red, green, amber, blue, opal or clear with miniature screw socket, candelabra screw socket or miniature bayonet socket. Choice of faceted or smooth jewel. All fit 1″ hole.

JOHNSON carries in stock a complete line of standard light assemblies to meet every ordinary need. Special assemblies, to meet your most exacting requirements, can also be furnished in production quantities on special order. Your inquiries are invited.

JOHNSON
E. F. JOHNSON CO. WASECA, MINN.

Crystals for the Critical

WHAT ARE YOUR CRYSTAL NEEDS?

No matter how specialized—or standardized—they may be, James Knights Co. is fully equipped to satisfy them quickly and economically.

To effect greater savings for you on short runs, a special production system has been established.

We are also equipped to quickly build "Stabilized" crystals to meet every ordinary need—precision built by the most modern methods and equipment.

For quality—speed—economy, contact the James Knights Co. You'll be glad you did!

"STABILIZED" CRYSTALS
To Meet Every Need

A WATCH TIMER MANUFACTURER wanted a crystal for use in timing standards. The James Knights Company designed a special unit and has delivered thousands of satisfactory crystals.

New James Knights Co. Catalog On Request.

The JAMES KNIGHTS Co.

SANDWICH, ILLINOIS

JK
CRYSTALS

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 59A)

Above-Chassis-Mounted Vertical Power Resistor

Described as the Standee, a new type vertical power resistor for above-chassis mounting, is announced by **Clarostat Mfg. Co., Inc.**, Washington St. Dover, N. H.

Basically, the Standee comprises a wire-winding on fibre-glass core, bent in hairpin form with mica separator between the legs, placed in a ceramic tube filled with cold-setting inorganic cement and provided with bottom terminals and mounting bracket. The lugs are locked into the tube wall, in addition to being sealed in cement. The Standee can be mounted above the chassis with a large hole to clear the terminals, and a small hole to take a self-tapping screw or rivet for the mounting bracket. By having this power resistor mounted above the chassis, the problem of heat dissipation is avoided.

Standees are available in the standard 19/32″ diameter, but in heights of 1½″, 2″, 2½″, and 3″, with respective power ratings of 10, 15, 20, and 25 watts. Maximum resistance values are 6,000, 9,000, 12,000 and 15,000 ohms, respectively. Standees are finished in the characteristic Greenohm green, and stamped with ohmage, brand name, and type number.

NOTICE

Information for our News and New Products section is warmly welcomed. News releases should be addressed to **Industry Research Division, Proceedings of I.R.E., Room 707, 303 West 42nd St., New York 18, N.Y.** Photographs, and electrotypes if not over 2″ wide, are helpful. Stories should pertain to products of interest specifically to radio engineers.

Laboratory Standards

STANDARD SIGNAL GENERATOR
Frequency range: 75 kc. to 30 mc. Output 0.1 microvolt to 2.2 volts.
MODEL 65B

STANDARD SIGNAL GENERATOR
Frequency range: 2 mc. to 400 mc. Output 0.1 microvolt to 0.1 volt.
MODEL 80

SQUARE WAVE GENERATOR
5 to 100,000 cycles. Recommended for AM, FM and television testing.
MODEL 71

MODEL 59
MEGACYCLE METER

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

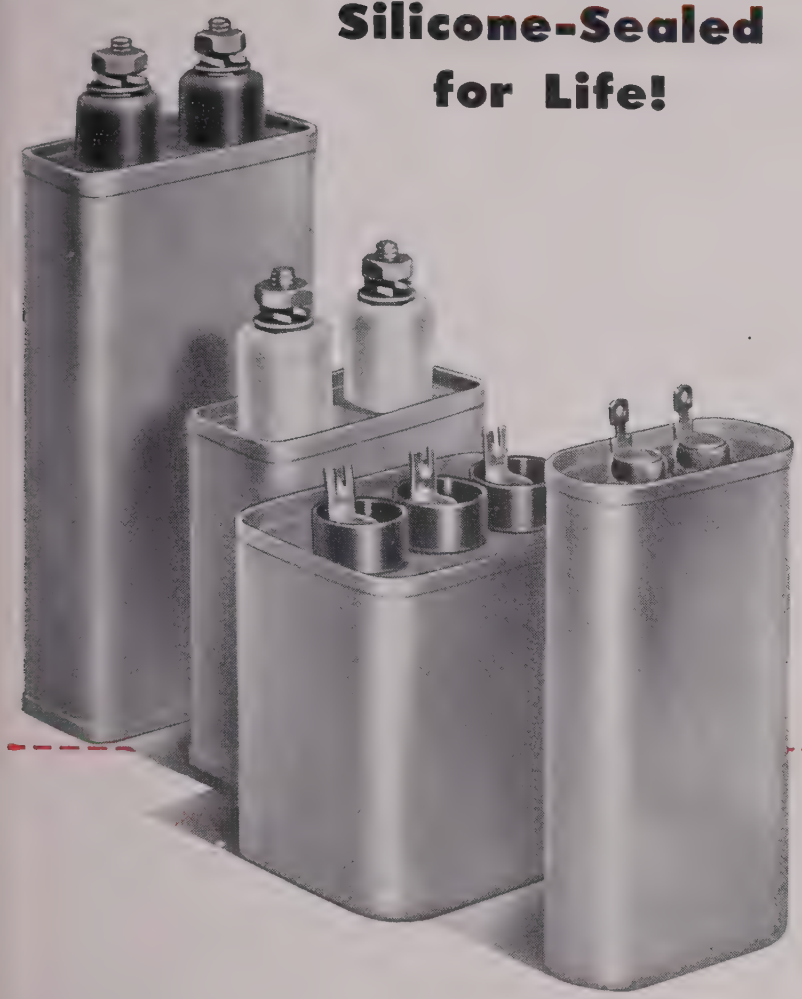
A versatile grid-dip oscillator covering the frequency range of 2.2 mc. to 400 mc.

CIRCULARS ON REQUEST

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

CAPACITORS

Silicone-Sealed for Life!



Silicone—the amazing new synthetic—made headlines when General Electric brought it out during the war. It's news again today—for G.E. has now made Silicone bushings and gaskets a *standard feature* of all its specialty capacitors up through 5000 volts.

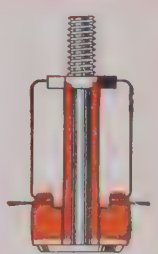
This means that your new G-E capacitor is sealed positively, permanently—for maximum life. For Silicone seals by compression alone, without the use of contaminating adhesives. It will never shrink, loosen or pull away—it remains elastic at any operating temperature a capacitor will ever meet. Moreover, it is impervious to oils, alkalies and acids, and its dielectric strength is permanently high.

This exclusive G-E feature—with the use of highest grade materials, with strictest quality control and individual testing—make General Electric capacitors finer and more dependable than ever before. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*

Silicone bushings used with capacitors 660-v a-c, or 1500-v d-c and lower.

Silicone bushings and plastic cups used with capacitors 660-v a-c, or 1500-v d-c and lower.

Silicone gaskets and plastic stand-offs used with capacitors rated 2000-v d-c and lower.



Silicone gaskets and porcelain stand-offs used with capacitors rated 2500-v to 5000-v d-c.

GENERAL ELECTRIC

Specialty Capacitors FOR

Motors
Luminous-tube transformers
Fluorescent lamp ballasts
Industrial control
Radio filters
Radar
Electronic equipment
Communication systems
Capacitor discharge welding
Flash photography
Stroboscopic equipment
Television
Dust precipitators
Radio interference suppression
Impulse generators

AND MANY OTHER APPLICATIONS

Proceedings of the I.R.E. June, 1949, Vol. 37, No. 6. Published monthly in two sections by The Institute of Radio Engineers, Inc., at [illegible] 79 Street, New York 21, N.Y. Price $2.25 per copy. Subscriptions: United States and Canada, $18.00 a year; foreign countries $19.00 a year. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized [illegible]

Table of contents will be found following page 32A

A HANDY LITTLE GADGET WE THINK YOU'LL LIKE

. . . Write for yours today

This Sprague Capacitor Indicator comes in mighty handy to engineers, designers or anyone else who works with capacitors. Fits the pocket. With it you can quickly convert the capacitor color code to capacitance, tolerance and voltage values; determine the availability of required capacitor types in the proper physical sizes, and read part numbers direct without cross reference or delay.

Write on company stationery for your Indicator today. We'll send it promptly—with our compliments.

PIONEERS OF **SPRAGUE** ELECTRIC AND ELECTRONIC PROGRESS

Capacitors

*Koolohm Resistors

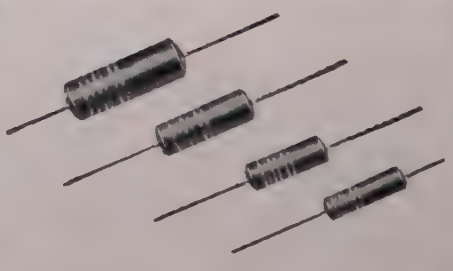
*Trademark Reg. U.S. Pat. Off.

SPRAGUE PHENOLIC MOLDED TUBULARS

The most important paper dielectric capacitor development since the war.

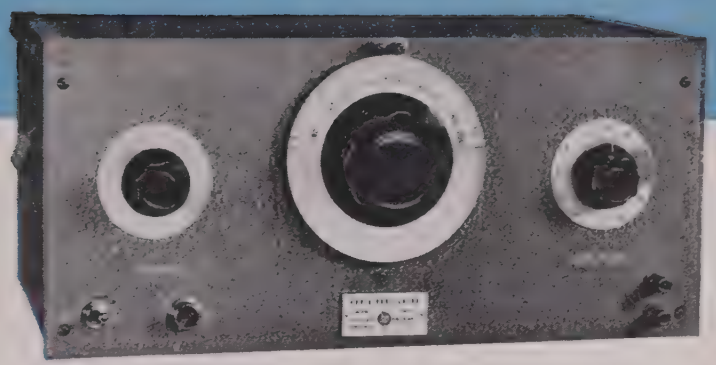
Smaller than conventional paper tubulars—highly heat- and moisture-resistant—non-inflammable—rugged—vibration-resistant—conservatively rated for −40°C. to +85°C. operation.

Write for Sprague Bulletin 210A. Samples on request to quantity users.



SPRAGUE ELECTRIC COMPANY, NORTH ADAMS, MASSACHUSETTS

hp OSCILLATORS GIVE YOU PRECISE TEST VOLTAGES from ½ cps to 10 mc!



–hp– MODEL 200C

From ½ cps to 10 mc, there's an *–hp–* resistance tuned oscillator engineered to your exact need. Ten precision oscillators in all, including a portable unit that operates from batteries. Each has the familiar *–hp–* advantages of high stability, constant output, wide frequency range, low distortion and no zero set during operation. *–hp–* precision oscillators are used by radio stations, manufacturers, research laboratories and scientists throughout the world.

SPECIFICATIONS OF –hp– OSCILLATORS

INSTRUMENT	FREQ. RANGE	OUTPUT	DISTORTION	FREQ. RESPONSE	PRICE
–hp– 200A	35 cps to 35 kc	1 watt/22.5v	Less than 1%	± 1 db to 15 kc	$120.00
–hp– 200B	20 cps to 20 kc	1 watt/22.5v	Less than 1%	± 1 db to 15 kc	120.00
–hp– 200C	20 cps to 200 kc	100 mw/10v	Less than 1% to 20 kc	± 1 db to 150 kc	150.00
–hp– 200D	7 cps to 70 kc	100 mw/10v	Less than 1% 10 cps to 70 kc	± 1 db throughout range	175.00
–hp– 200H	60 cps to 600 kc	10 mw/1v	Less than 3%	± 1 db, 60 cps to 600 kc	350.00
–hp– 200I	6 cps to 6 kc	100 mw/10v	Less than 1% above 10 cps	± 1 db, 6 to 6000 cps	225.00
–hp– 201B	20 cps to 20 kc	3 w/42.5v	Less than ½% (1 watt output)	± 1 db throughout range	250.00
–hp– 202B	½ cps to 50 kc	100 mw/10v	Less than 1% 1 to 1000 cps	± 1 db, 10 to 50,000 cps	350.00
–hp– 202D	2 cps to 70 kc	100 mw/10v	Less than 2% 10 cps to 70 kc	± 1 db, 7 cps to 70 kc	275.00
–hp– 204A (Battery Op'd.)	2 cps to 20 kc	2.5 mw/5v	Less than 1%	± 1 db throughout range	175.00
–hp– 650A	10 cps to 10 mc	15 mw/3v	Less than 1% 100 cps to 100 kc	± 1 db throughout range	475.00

For complete details on any –hp– instrument, write direct to factory or contact the –hp– technical representative nearest you.

HEWLETT-PACKARD CO.
1855-D Page Mill Road, Palo Alto, California
Export Agents: Frazar & Hansen, Ltd.
301 Clay Street • San Francisco, Calif., U. S. A.

ANOTHER -hp- SERVICE

Person-to-Person Help With Your Measuring Problems

Almost anywhere in America, *–hp–* field representatives can give you personal help with your measuring problems. They have complete data on *–hp–* instruments, their performance, servicing and adaptability. Call the nearest *–hp–* field representative whenever, wherever you need help with a measuring problem.

BOSTON, MASSACHUSETTS
Burlingame Associates
270 Commonwealth Ave.
KEnmore 6-8100

CHICAGO 6, ILLINOIS
Alfred Crossley & Associates
549 W. Randolph St.
State 7444

CLEVELAND 12, OHIO
M. P. Odell
1748 Northfield Avenue
Potomac 6960

DALLAS 5, TEXAS
Earl W. Lipscomb
4433 Stanford Street
Logan 6-5097

DENVER 10, COLORADO
Ronald G. Bowen
1896 So. Humboldt Street
Spruce 9368

FORT MYERS, FLORIDA
Arthur Lynch and Associates
P. O. Box 466
Fort Myers 1269M

HIGH POINT, NORTH CAROLINA
Bivins & Caldwell
Room 807, Security Bank Building
Phone 3672

LOS ANGELES 46, CALIFORNIA
Norman B. Neely Enterprises
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Whitney 1147

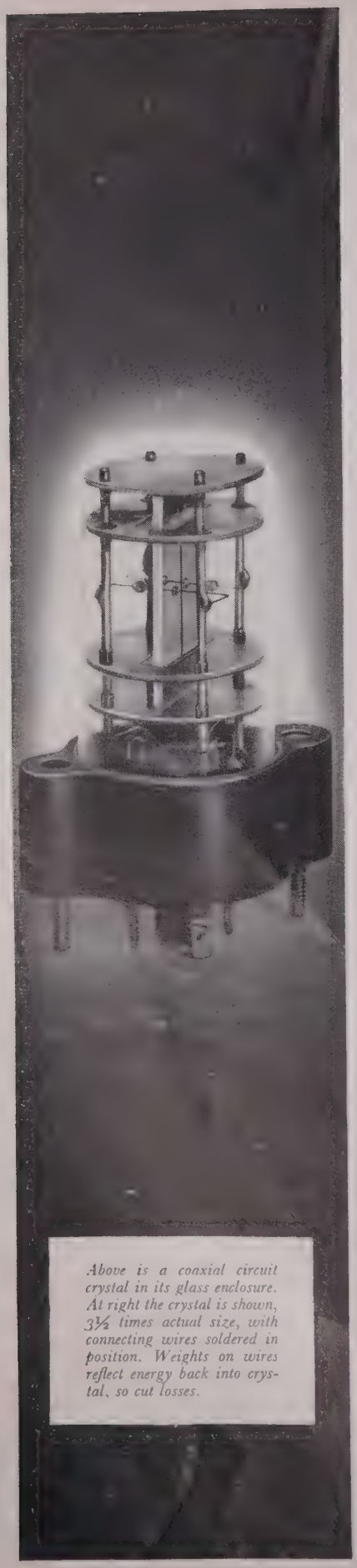
NEW YORK 7, NEW YORK
Burlingame Associates
11 Park Place
Digby 9-1240

SAN FRANCISCO 3, CALIFORNIA
Norman B. Neely Enterprises
954 Howard Street
Douglas 2-2609

TORONTO 1, CANADA
Atlas Radio Corporation, Ltd.
560 King Street West
Waverley 4761

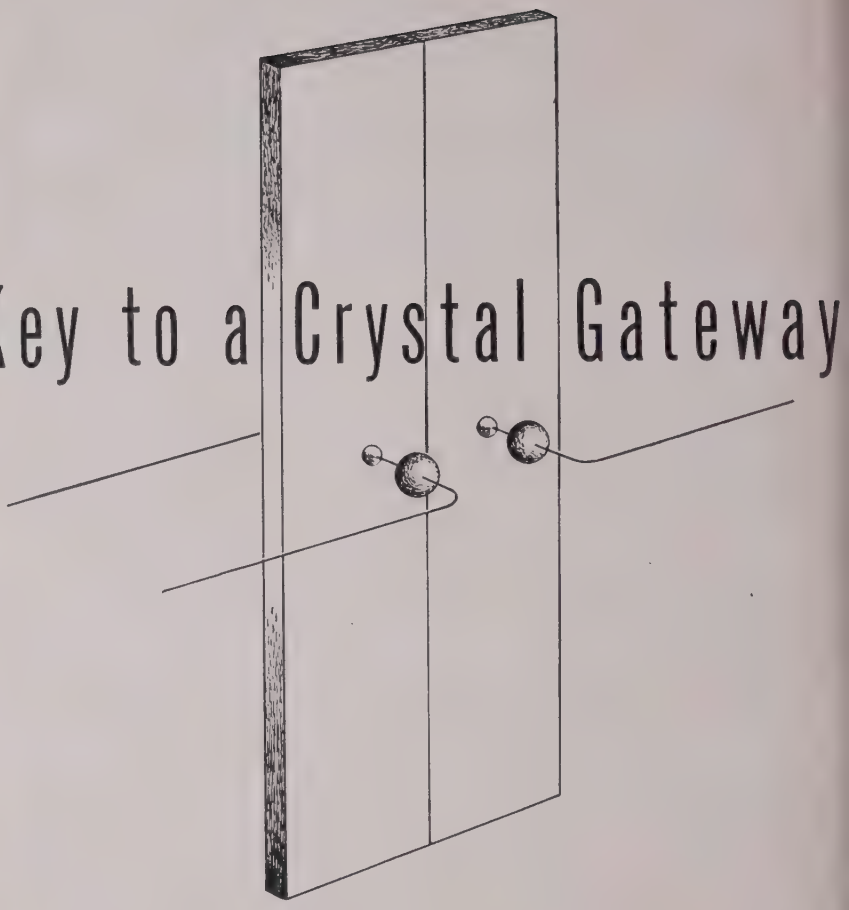
WASHINGTON 9, D. C.
Burlingame Associates
2017 S. Street N. W.
Decatur 8000

hp laboratory instruments
FOR SPEED AND ACCURACY



Above is a coaxial circuit crystal in its glass enclosure. At right the crystal is shown, 3½ times actual size, with connecting wires soldered in position. Weights on wires reflect energy back into crystal, so cut losses.

Key to a Crystal Gateway



How would you solder a wire to a crystal? This must be done for most of those wafer-thin plates of quartz used in electrical circuits. They play a big part in the myriad-channel telephone system that utilizes coaxial cables.

This is how Bell Laboratories scientists solved the problem: A spot of paste containing silver is deposited on the crystal and bonded to it by oven heat. The crystal is then vapor-plated with a thin layer of silver. Then a fine wire is soldered to the spot by a concentrated blast of hot air. The result is a rugged electrical connection to the surface of the crystal which does not interfere with its vibrations.

Sealed in glass tubes, the crystals are precise and reliable performers in the telephone system. Each is a crystal gate to a voiceway, separating *your* conversation from the hundreds of others which may be using a pair of coaxial conductors, at the same time.

This spot of paste, this tiny wire, this puff of air are among the tremendous trifles which concern Bell Telephone Laboratories in finding new ways to improve your telephone service.

BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING, FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE

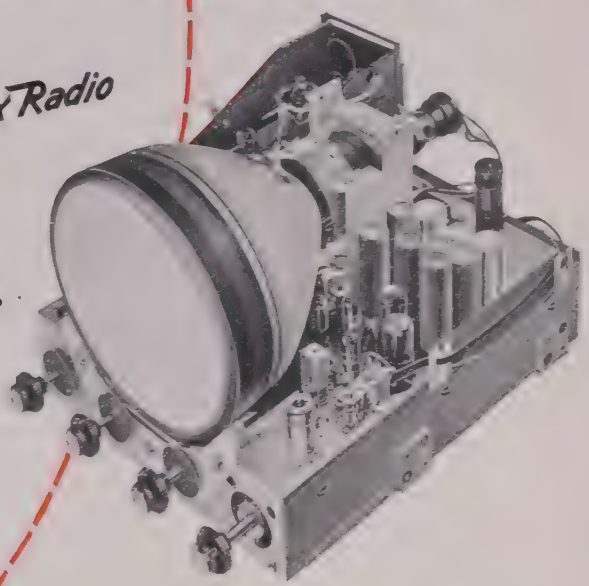
HI-Q COMPONENTS

Specified by

The Leaders in Radio-TV & Communications

Emerson
FADA
Bendix Radio
Motorola
RAYTHEON BELMONT
Admiral
RCA VICTOR
Packard-Bell
Magnavox
Farnsworth
CROSLEY
Andrea
DUMONT
Tele-tone

—and many others too numerous to list in this limited space.



Chassis of the popular EMERSON Model 611 Television set. **HI-Q** components contribute their part to dependable operation.

Look at the leaders in Radio, Television and Communications, and you'll find *they* look to **HI-Q** for quality components.

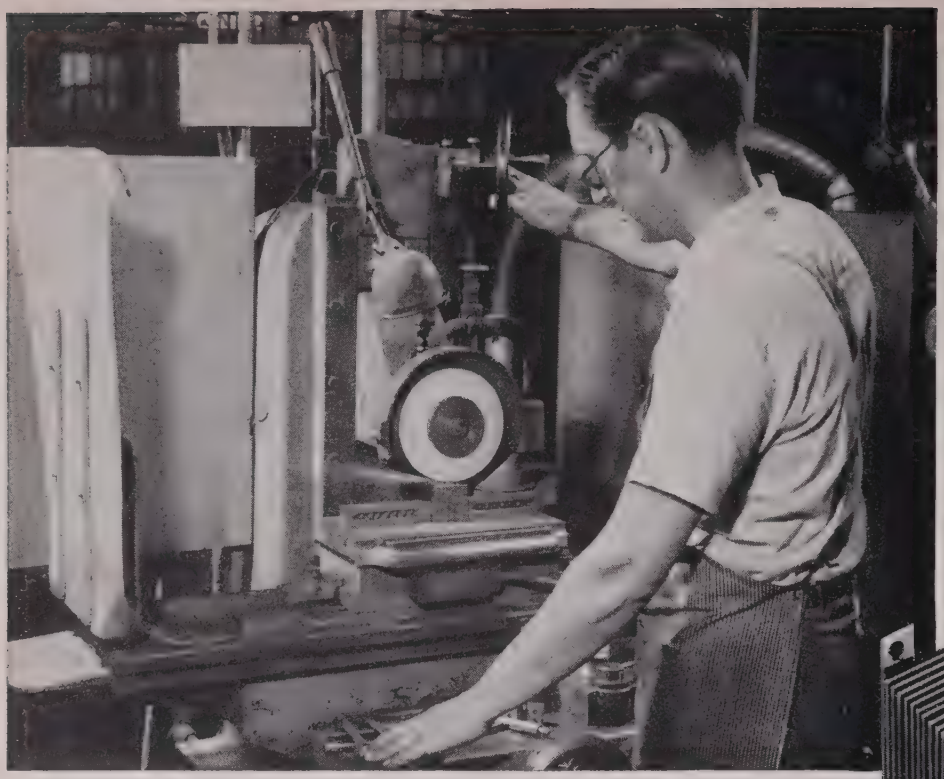
HI-Q engineers have worked closely with many of these companies in the development of electronic components demanded by the ever changing circuits of modern electronics.

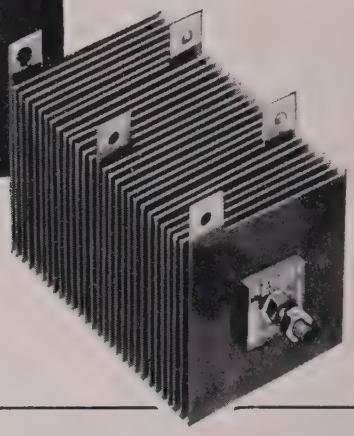
These same engineers with their wide experience are available to your company for confidential consultation. Write—wire—or phone. Three (3) plants exclusively devoted to the manufacture of ceramic capacitors, resistors and choke coils assure prompt delivery of your orders.

HI-Q *Electrical Reactance Corp.*

FRANKLINVILLE, N. Y.

Plants: FRANKLINVILLE, N. Y.—JESSUP, PA.—MYRTLE BEACH, S. C.
Sales Offices: NEW YORK, PHILADELPHIA, DETROIT, CHICAGO, LOS ANGELES





"...Worked So Well We've Forgotten About It!"

That's the kind of report we like to hear—because it describes a Mallory Magnesium-Copper Sulfide Rectifier Stack which has served *ten years—in daily operation—with minimum maintenance.* Its job—supplying DC current for the operation of a magnetic chuck on each of five surface grinders such as the one shown above. Its performance—it still gives over 90% of its original efficiency.

This is not surprising. Mallory Magnesium-Copper Sulfide Rectifier Stacks are made rugged—practically immune to damage or abuse. Rectification is confined to core of the stack—the outside fins are for heat dissipation only. No liquids, bulbs or moving parts—nothing to give trouble or wear out. And Mallory Mg-CuS rectifier stacks are more than "the world's toughest rectifiers"—when subjected to abnormal voltage surges, their rectifying junctions are so made that they actually heal themselves.

No wonder millions are in use. Write for more information or for engineering help.

Check These Features:

- √ **Proved long life**
- √ **Unaffected by high temperatures**
- √ **Withstands abuse and accidental short circuits**
- √ **Self-healing rectifying junctions**
- √ **Constant output over many years**
- √ **Resists harmful atmospheric conditions**
- √ **Rugged, all-metal construction**
- √ **No bulbs, no brushes, no sparking contacts**

Mg-CuS Rectifier Stacks and Power Supplies

P.R. MALLORY & CO., Inc.

MALLORY

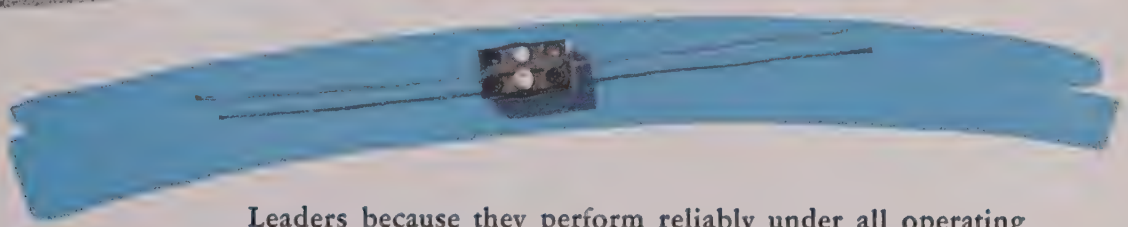
P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WITH

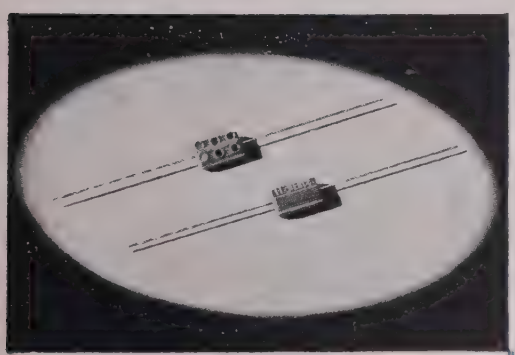
Capacitors — Rectifiers
Contacts — Switches
Controls — Vibrators
Power Supplies
Resistance Welding Materials

EL-MENCO CAPACITORS

Leaders



Leaders because they perform reliably under all operating conditions, these fixed mica dielectric capacitors are used in electronic applications wherever long life and successful performance are demanded.



CM 15 MINIATURE CAPACITOR

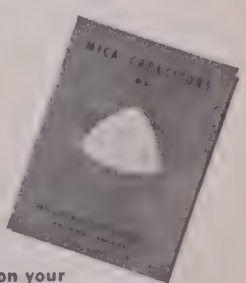
Actual Size $\frac{9}{32}$" x $\frac{1}{2}$" x $\frac{3}{16}$"
For Radio, Television and Other Electronic Applications
2 to 420 mmf. capacity at 500vDCw
2 to 524 mmf. capacity at 300vDCw
Temp. Co-efficient ±50 parts per million per degree C for most capacity values
6-dot standard color coded

Each tiny El-Menco Capacitor must pass life and humidity tests; meet standards set by the United States Army and Navy; pass tests at double their working voltages; prove their dielectric strength, temperature co-efficient and capacitance drift, and have their insulation resistance double-checked. These little leaders are molded in low-loss bakelite and wax-dipped for salt water immersion seal. They're available in a wide range, all impregnated, all precision-made, all JAN, RMA and RCM color-coded.

Why not protect your product's performance with capacitors made under these rigid conditions?

Specify **EL-MENCO**
TESTED● RELIABLE● LEADERS!

THE ELECTRO MOTIVE MFG. CO., Inc.
WILLIMANTIC CONNECTICUT



Write on your firm letterhead for Catalog and Samples

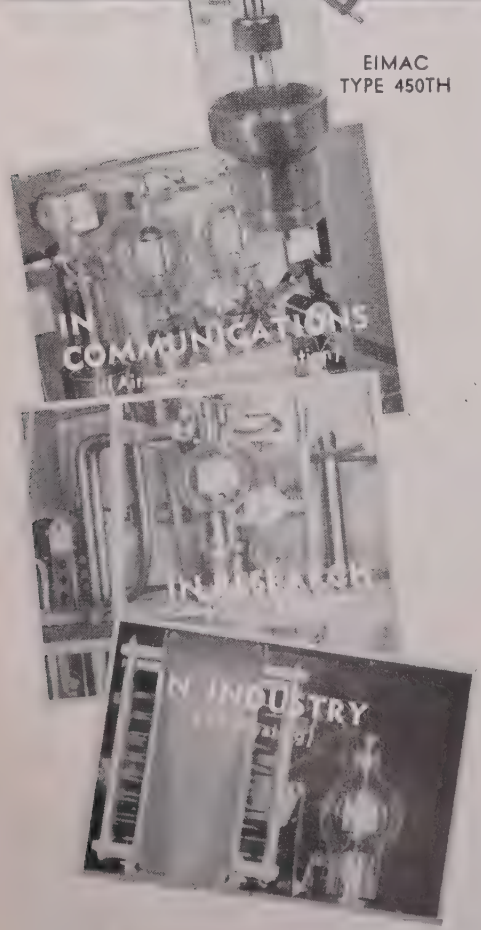
MOLDED MICA El-Menco MICA TRIMMER CAPACITORS

FOREIGN RADIO AND ELECTRONIC MANUFACTURERS COMMUNICATE DIRECT WITH OUR EXPORT DEPT. AT WILLIMANTIC, CONN.
ARCO ELECTRONICS, INC. 135 Liberty St., New York, N. Y.—Sole Agent for Jobbers and Distributors in U.S. and Canada

Follow the Leaders to
Eimac TUBES
The Power for R-F

Today, ever increasing demands for the famous Eimac triodes keep assembly lines producing record-breaking quantities.

Proven Acceptance



EIMAC
TYPE 450TH

Many years of reliable service in many types of application have established the Eimac 450T as the standout triode in its power class.

Recent technical achievements make the 450T a still better tube. Adoption of the Pyrovac plate and a non-emitting grid have amplified this already rugged tube's ability to "take it." Life expectancy and overload handling qualities have been increased multifold.

Comprehensive technical data on the Eimac 450T are immediately available . . . write direct.

EIMAC TYPE 450TH
ELECTRICAL CHARACTERISTICS

Filament: Thoriated tungsten	
Voltage	7.5 volts
Current	12.0 amperes
Amplification Factor (Average)	38
Direct Interelectrode Capacitances (Average)	
Grid-plate	5.0 μufd.
Grid-filament	8.8 μufd.
Plate-filament	0.8 μufd.
Transconductance (I_b=500 ma., E_b=4000v.)	6650 μmhos

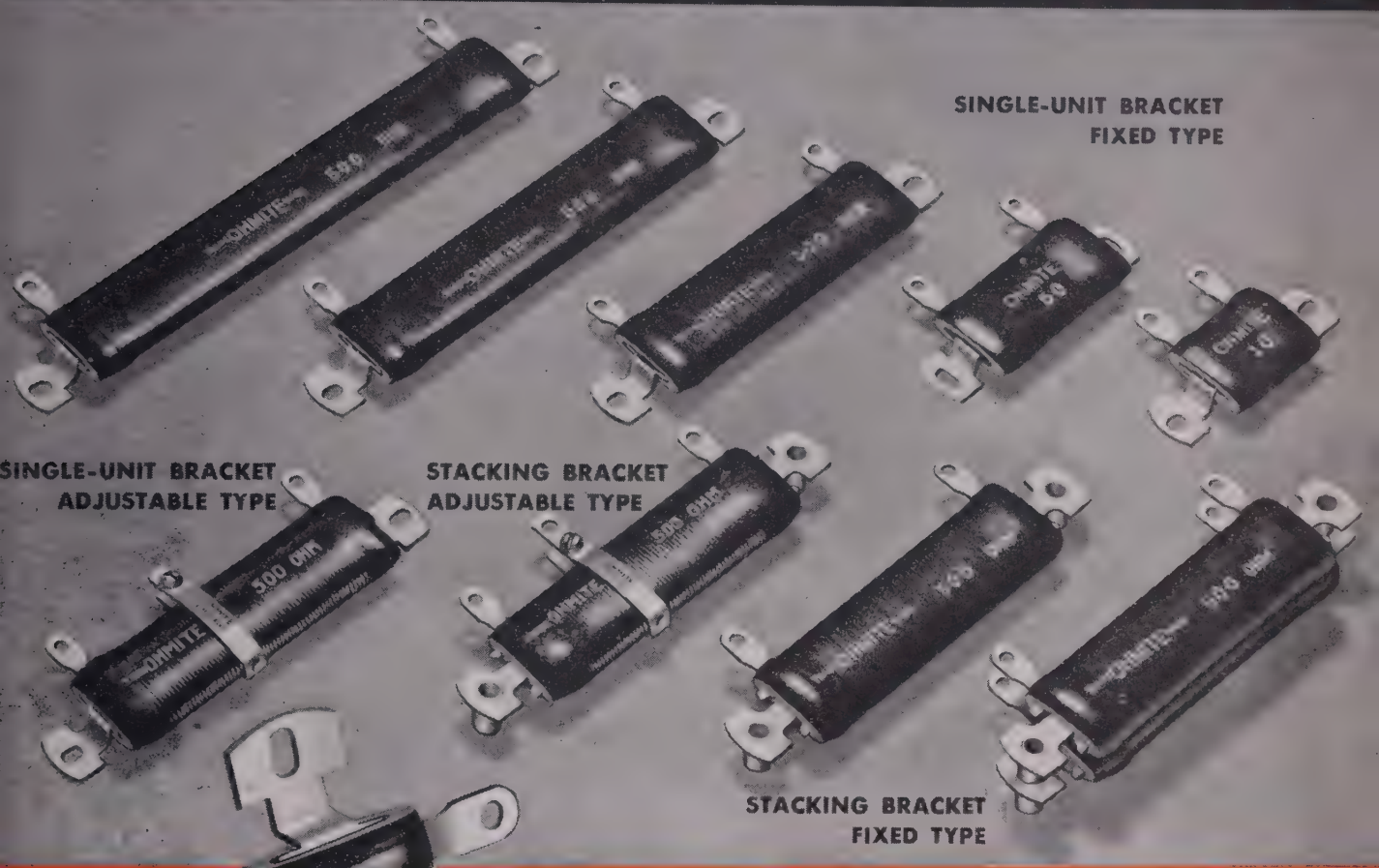
MAXIMUM RATINGS
Radio Frequency Power Amplifier and Oscillator
Class-C Telegraphy (Key-down conditions, 1 tube)
Frequencies below 40 Mc.

D-C Plate Voltage	6000 Max. Volts
D-C Plate Current	600 Max. Ma.
Plate Dissipation	450 Max. Watts
Grid Dissipation	65 Max. Watts

EITEL-McCULLOUGH, INC.
728 San Mateo Ave., San Bruno, California
Export Agents: Frazar & Hansen, 301 Clay St., San Francisco, California

217

OHMITE THIN RESISTORS



VITREOUS-ENAMEL COVERING

Winding is rigidly held in place and protected from damage by Ohmite special vitreous enamel.

EVEN, UNIFORM WINDING

"Hot spots" and resultant failures are prevented by the resistance winding's unsurpassed uniformity.

STRONG, CERAMIC CORE

Unaffected by cold, heat, fumes, or high humidity, its core provides a strong base for winding.

FIVE WATTAGE SIZES

Lengths range from 1 inch to 6 inches, corresponding to ratings of 30 to 75 watts.

INTEGRAL MOUNTING BRACKETS

Distribute heat more evenly throughout resistor and conduct heat away quickly.

...PACK HIGHER WATTAGE INTO LESS SPACE

Because of their compact design, Ohmite Thin Type Resistors have a higher wattage rating per unit of space. They provide all the time-proven superiority of conventional Ohmite vitreous-enamel resistors—giving you a compact unit you can depend upon. Available in four types—all only ¼ inch thick by 1 inch wide—in five lengths and a wide range of resistance values.

Send for Bulletin No. 138

OHMITE MANUFACTURING CO.
4862 W. Flournoy St., Chicago 44, Ill.

Be Right with

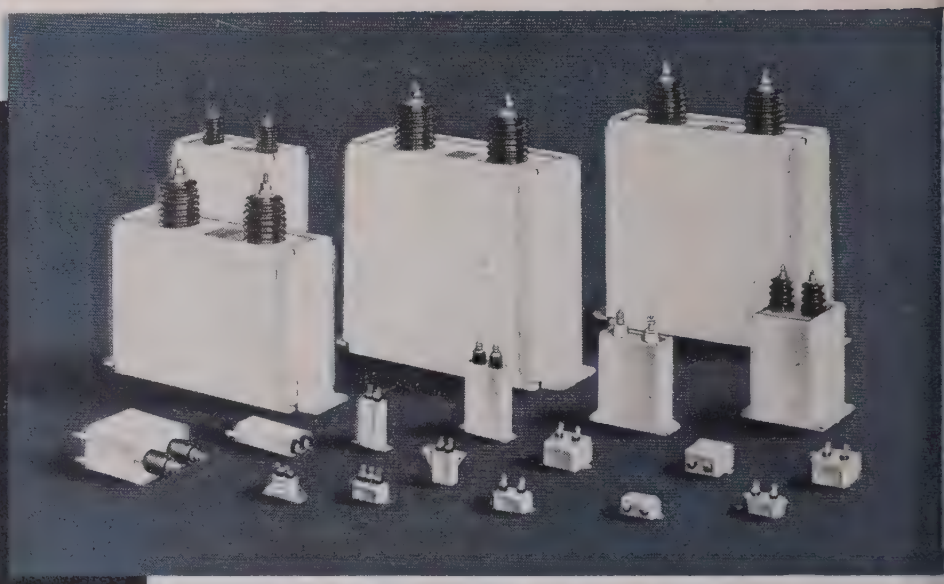
OHMITE

RHEOSTATS • RESISTORS • TAP SWITCHES

ELECTRONICS

Designers

take your choice...
FIXED
PAPER-DIELECTRIC
CAPACITORS



Readily available for DC electronic applications, these capacitors are manufactured in accordance with joint Army-Navy specifications JAN-C-25. Case styles include types CP 53, CP 54, CP 55, CP 61, CP 63, CP 65, CP 67, CP 69 and CP 70. Capacitance ratings are from .01 Muf to 15 Muf, and voltage ratings are listed from 100 to 12,500 volts.

These capacitors are constructed with thin Kraft paper, oil or Pyranol* impregnated, which provides stable characteristics and high dielectric strength. Plates are aluminum foil, manufactured according to detailed specifications. Special bushing construction provides for short internal leads, preventing possible grounds and short circuits. The cases have a permanent hermetic seal to provide longer life. A variety of mounting arrangements are available for various installation requirements. Write for detailed description and operating data: Bulletin GEA-4357A.

*Pyranol is General Electric's non-inflammable liquid dielectric for capacitors.

Less than one inch long, and only one inch square, this postage-stamp-size selenium rectifier offers radio builders substantial savings in production costs. Only two soldering operations and a minimum of hardware are necessary for installation in places where a rectifier tube and socket won't fit. They're built to safely withstand the inverse peak voltages obtained when rectifying (half-wave) 110-125 volts, rms, and feeding a capacitor as required in various radio circuits. Tests prove that selenium rectifiers will outlast the conventional type of rectifier tubes, at the same time costing less. Send for bulletin GEA-5238.

GENERAL ELECTRIC

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

HOLDS OUTPUT VOLTAGE CONSTANT

This 500-va voltage stabilizer is suitable for a wide variety of electronic applications where constant voltage is demanded. Voltage variations from 95 to 130 volts are absorbed almost instantaneously and output voltage maintained at 115 volts (plus or minus 1 percent). There are no moving parts, no adjustments to make. This unit will operate continuously at no load or short circuit without damage to itself. It will limit the short circuit current to approximately twice stabilizer's normal full load current rating. Other sizes available range from 15 to 5000 va. For details, check bulletin GEA-3634B.

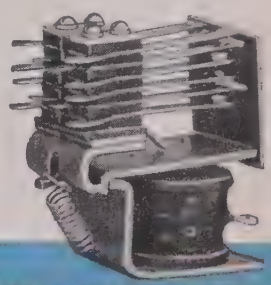
WANT TO TIME TUBE LIFE?

Suitable for installation in radio transmitters, these G-E time meters provide accurate record of tube operating time. They record in hours, tenths of hours, or minutes. Ratings range from 11 to 460 volts. Installation on a panel or switchboard is simplified by quick-wiring leads. Timer harmonizes with other panel instruments in appearance and size. Dependability is assured by Telechron* motor drive. Also available for portable use or conduit and junction box mounting. Check bulletin GEC-472.

FOR YOUR TELEVISION SETS

General Electric's television cord set comes in 6-foot lengths, made of 2/18 Pot-64 brown Flamenol* rip-cord. Set has brown plastic plug and new brown Flamenol connector molded on opposite end. Rip-cord has smooth finish, resists oil, water, acids, alkalies, or sunlight deterioration. Rating is 7 amps., no. 18 wire. Set is designed for assembly on television receiver rear panel, automatically disconnects when panel is removed. Write for further information.

*Trademark Reg. U. S. Pat. Off.



DEPENDABLE CONTROL FOR AUTOMATIC DEVICES

G.E.'s multi-contact relays are inexpensive units built specifically for appliances and vending machines. Construction features assure quiet, reliable operation, and compactness makes them adaptable to a variety of devices such as coin changers, phonographs, and television receivers. Single-circuit contacts or combinations of contacts for multi-circuit application are attached to the same sturdy frame and coil assembly, affording a multiplicity of relay forms. Ratings are 5 amperes at 115 volts or 24 volts, a-c or d-c. Get details from Bulletin GEC-306.

General Electric Company, Section H667-1
Apparatus Department, Schenectady, N. Y.

Please send me the following bulletins:

- ☐ GEA-3634B Voltage Stabilizers
- ☐ GEA-4357A D-C Capacitors
- ☐ GEA-5238 Selenium Rectifiers
- ☐ GEC-306 Multi-contact Relays
- ☐ GEC-472 Tube Timers

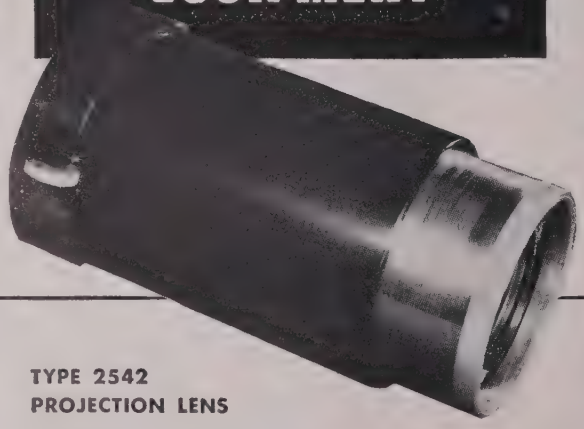
NAME .....

COMPANY .....

ADDRESS .....

CITY ..... STATE .....

Consider the possibilities of this combination of DU MONT CATHODE-RAY EQUIPMENT

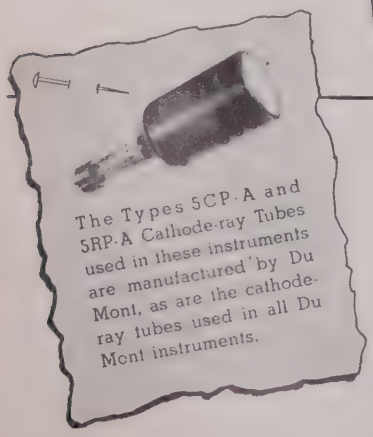


TYPE 263-B
HIGH-VOLTAGE POWER SUPPLY

The Type 263-B High-Voltage Power Supply is designed to complement the Type 250-H Cathode-ray Oscillograph, a slightly modified version of the Type 250. This combination operates the Type 5RP-A Cathode-ray Tube in the Type 250-H instrument at accelerating potentials as high as 13,700 volts, permitting the photographic recording of writing rates as high as 40 inches per microsecond. The light output of the Type 250-H with the Type 263-B is 12 times greater than that of the Type 250 alone.

TYPE 250
CATHODE-RAY OSCILLOGRAPH

An excellent general-purpose cathode-ray oscillograph designed for observing and recording recurrent and transient phenomena. Contains both a-c and d-c amplifiers. Linear sweeps, driven and recurrent, from 1 cycle to 150 kc with automatic beam blanking on driven sweep. Deflection factor through a-c amplifier, 0.015 rms volt/in. max.; through d-c amplifier, 2 d-c volts/in. Built-in calibrator permits quantitative measurements. The high-current Type 5CP-A Cathode-ray Tube is operated at 3000 accelerating volts in this instrument to provide brilliance adequate for nearly all laboratory work.



The Types 5CP-A and 5RP-A Cathode-ray Tubes used in these instruments are manufactured by Du Mont, as are the cathode-ray tubes used in all Du Mont instruments.

TYPE 2542
PROJECTION LENS

With the addition of Type 2542 Projection Lens, the Type 250-H becomes a projection oscillograph capable of projecting its trace up to 30 feet for a picture size as large as 12 feet square. Advantages of such projections for lecture or demonstration work are readily apparent.

Lastly, the Du Mont Types 271-A and 314-A Oscillograph-record Cameras may be readily mounted on the Types 250 and 250-H for permanent recording.

DETAILED LITERATURE ON REQUEST

•

EQUIPMENT DEMONSTRATED

No obligation

© ALLEN B. DU MONT LABORATORIES, INC.

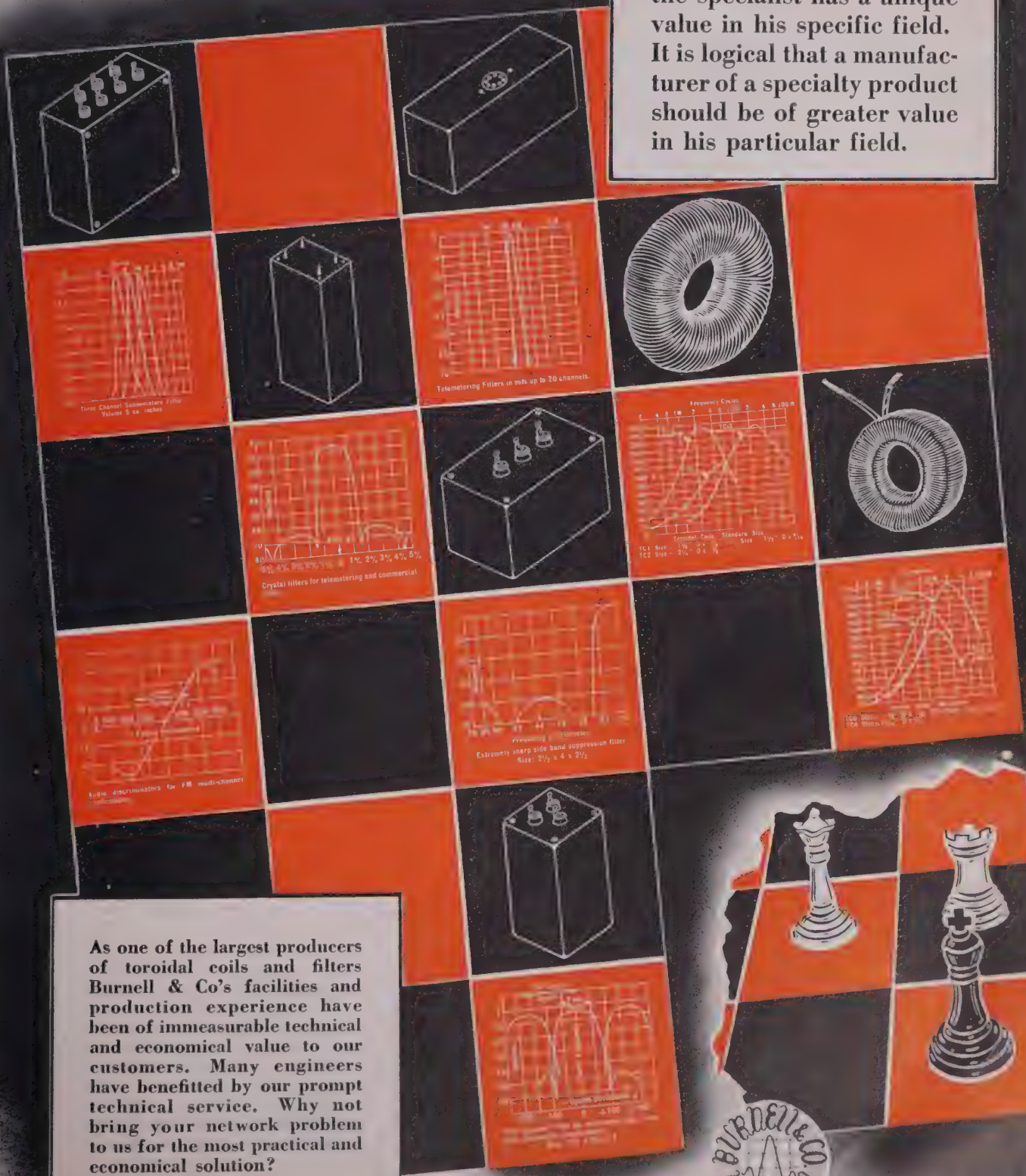
DUMONT for Oscillography

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
CABLE ADDRESS: ALBEEDU, NEW YORK, N. Y., U.S.A.

INSTRUMENT DIVISION • 1000 MAIN AVENUE • CLIFTON, N. J.

Check YOUR NETWORK PROBLEM WITH LOGIC

In any technical business the specialist has a unique value in his specific field. It is logical that a manufacturer of a specialty product should be of greater value in his particular field.


Three Channel Subminiature Filter
Volume 5 cu. inches
Telemetering Filters in sets up to 20 channels.
Crystal filters for telemetering and commercial
Extremely sharp side band suppression filter
Size: 2½ x 4 x 2½

As one of the largest producers of toroidal coils and filters Burnell & Co's facilities and production experience have been of immeasurable technical and economical value to our customers. Many engineers have benefitted by our prompt technical service. Why not bring your network problem to us for the most practical and economical solution?

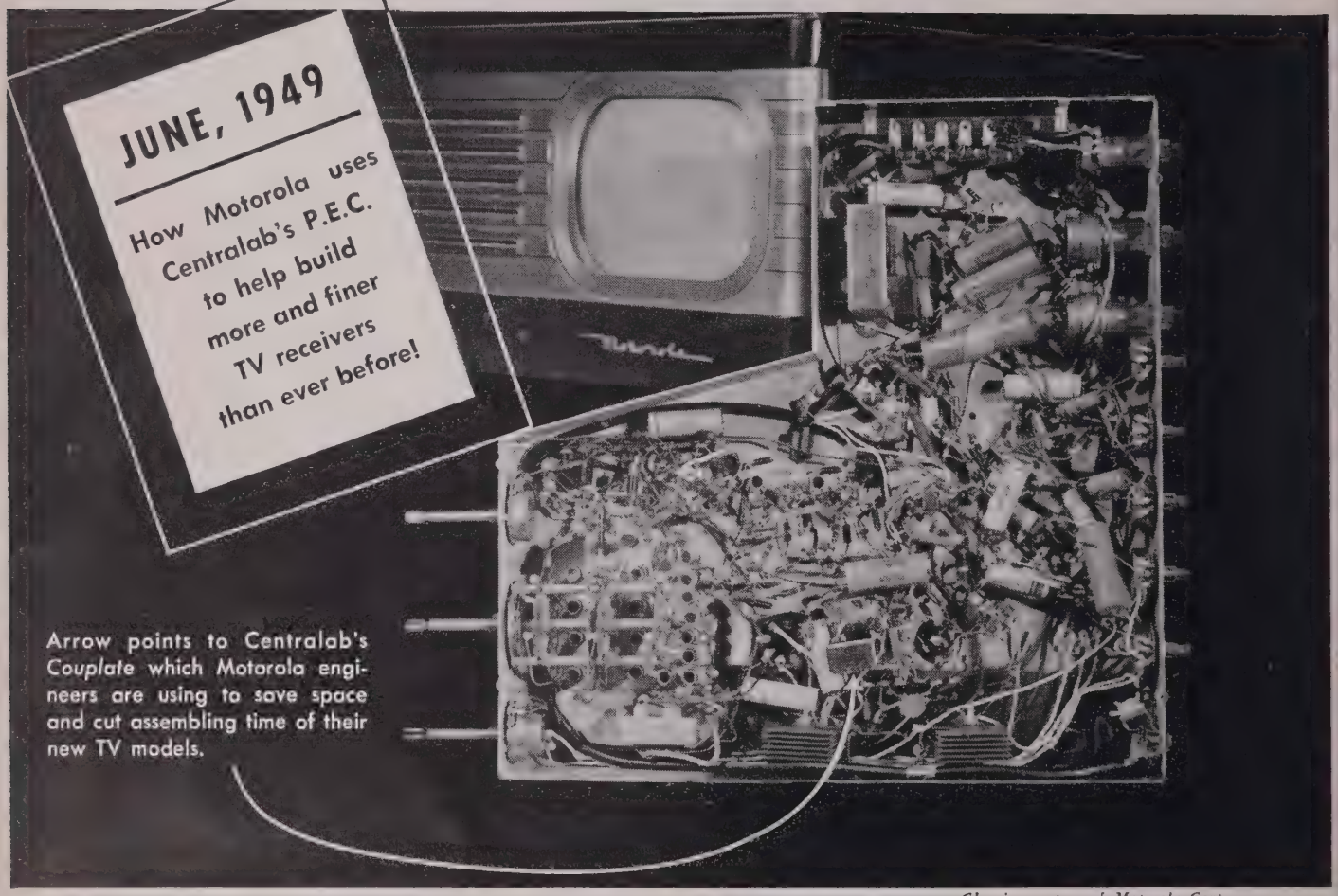
EXCLUSIVE MANUFACTURERS OF COMMUNICATIONS NETWORK COMPONENTS

WRITE FOR TECHNICAL INFORMATION
ALL INQUIRIES WILL BE PROMPTLY HANDLED

BURNELL & CO.

Burnell & Company
YONKERS 2, NEW YORK
CABLE ADDRESS "BURNELL"

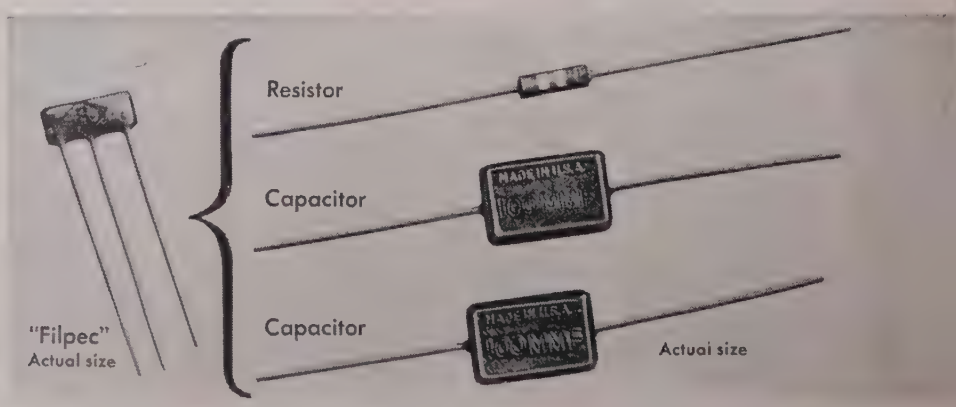
Centralab reports to


JUNE, 1949
How Motorola uses Centralab's P.E.C. to help build more and finer TV receivers than ever before!
Arrow points to Centralab's *Couplate* which Motorola engineers are using to save space and cut assembling time of their new TV models.

Chassis courtesy of Motorola Corp.

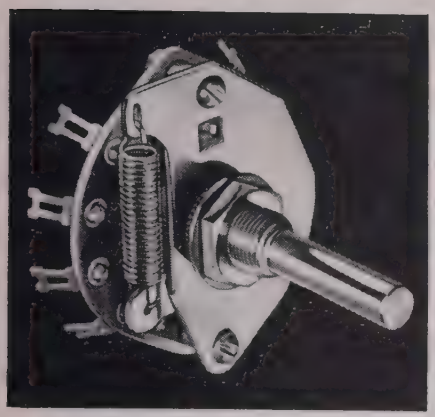
1 Speeded production and finer products go hand in hand where CRL's amazing *Printed Electronic Circuit* is concerned. Take the case of Motorola's new TV sets. Engineers at Motorola find that CRL's *Couplate* — a printed interstage coupling plate — saves production time by cutting in half the number of soldered connections... speeds assembly by simplifying wiring operations. They also find it helps produce finer receivers by eliminating loose or broken connections—from plate load resistor to coupling capacitor.

2 CRL's *Couplate* consists of a plate lead resistor, grid resistor, plate by pass capacitor and coupling capacitor. Write for Bulletin 42-6.

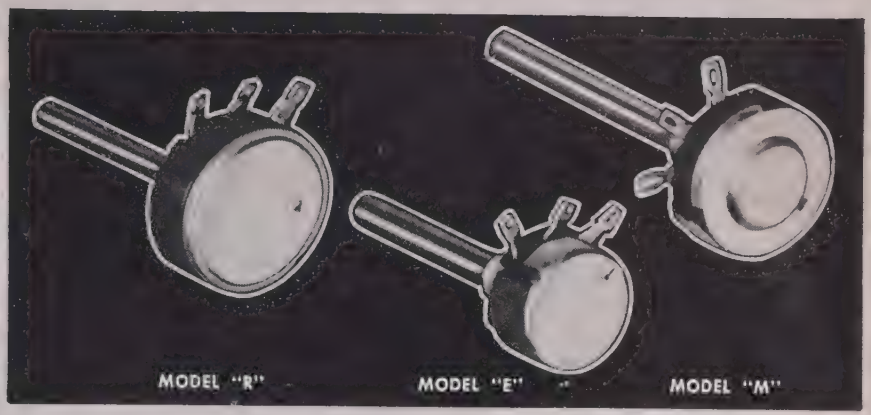


3 Centralab's *Filpec* is designed for use as a balanced diode load filter, combines up to three major components into one tiny unit, lighter and smaller than one ordinary capacitor. Capacitor values from 50 to 200 mmf. Resistor values from 5 ohms to 5 megohms. For complete information, write for Bulletin 42-9.

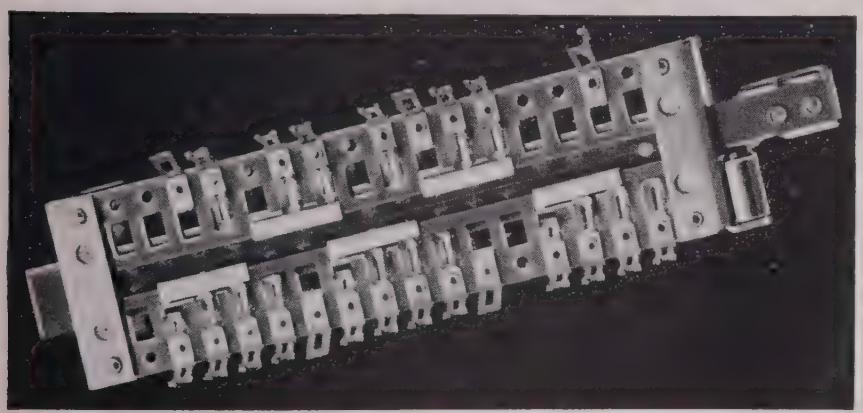
Electronic Industry



4 Great step forward in switching is CRL's New *Rotary Coil and Cam Index Switch.* Its coil spring gives you smoother action, longer life.



5 Let Centralab's complete *Radiohm* line take care of your special needs. Wide range of variations: *Model "R"* — wire wound, 3 watts; or composition type, 1 watt. *Model "E"* — composition type, ¼ watt. Direct contact, 6 resistance tapers. *Model "M"* — composition type, ½ watt. Write for Bulletin 697.



6 Centralab's development of a revolutionary, new *Slide Switch* promises improved AM and FM performance! Flat, horizontal design saves valuable space, allows short leads, convenient location to coils, reduced lead inductances for increased efficiency in low and high frequencies. Rugged, efficient. Write for Bulletin 953.

7 For by-pass or coupling applications, check CRL's original line of ceramic disc and tubular *Hi-Kaps.* For full facts, order Bulletins 42-3 and 42-4.

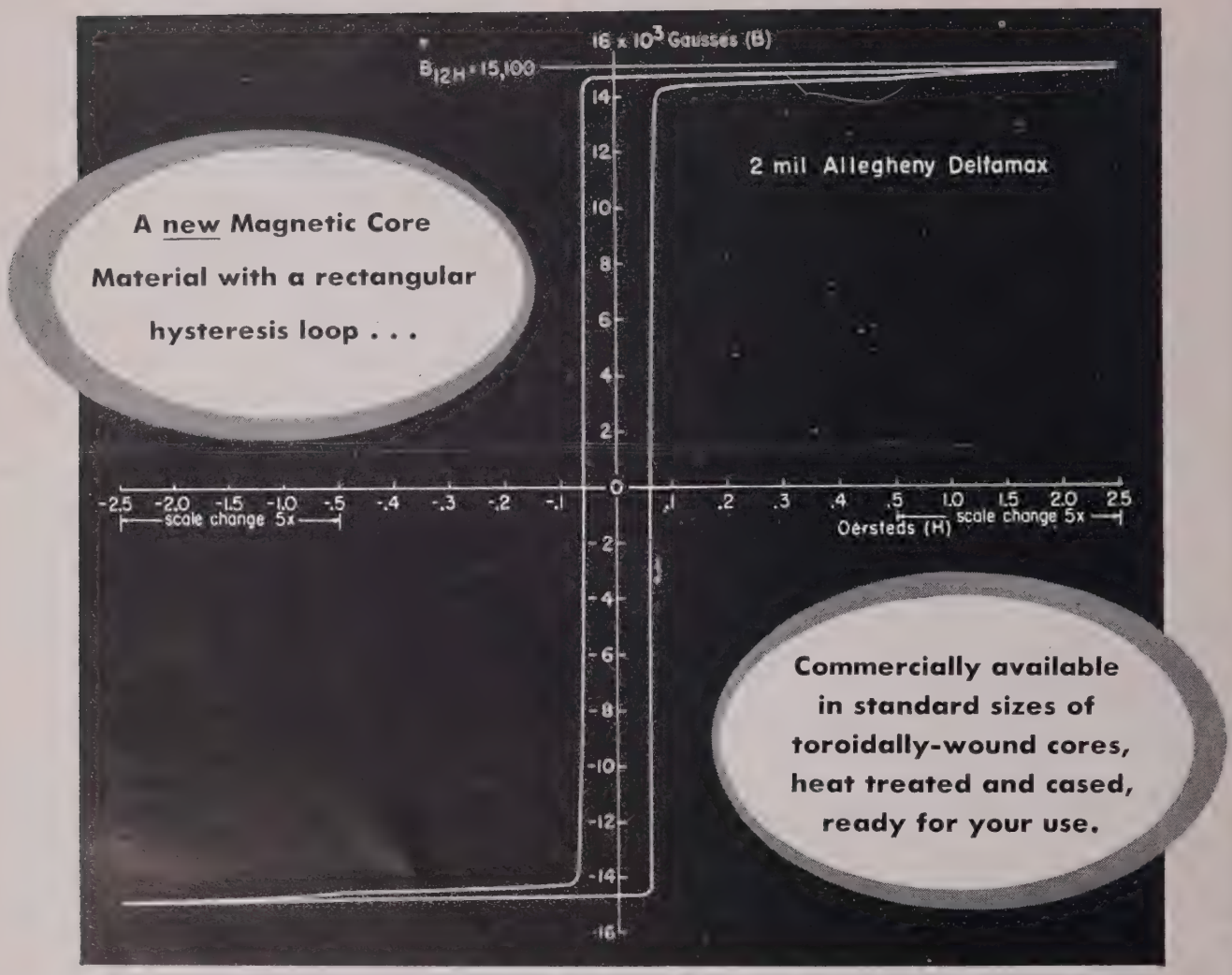
LOOK TO CENTRALAB IN 1949! ***First in component research that means lower costs for the electronic industry. If you're planning new equipment, let Centralab's sales and engineering service work with you. Get in touch with Centralab!***

Centralab

CRL ®

DIVISION OF GLOBE-UNION INC., MILWAUKEE, WIS.

DELTAMAX—now available!


16 x 10³ Gausses (B)
B12H = 15,100
2 mil Allegheny Deltamax
A new Magnetic Core Material with a rectangular hysteresis loop . . .
-2.5 -2.0 -1.5 -1.0 -.5 -.4 -.3 -.2 -.1
scale change 5x
.1 .2 .3 .4 .5 1.0 1.5 2.0 2.5
Oersteds (H)
scale change 5x
14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14 -16
Commercially available in standard sizes of toroidally-wound cores, heat treated and cased, ready for your use.

Where can YOU use a Magnetic Material with these specialized, dependable characteristics?

The properties of Deltamax are invaluable for many electronic applications, such as new and improved types of mechanical rectifiers, magnetic amplifiers, saturable reactors, peaking transformers, etc. This new magnetic material is available now as "packaged" units (cased cores ready for winding and final assembly) distributed by the Arnold organization. Every step in manufacture has been fully developed; designers can rely on complete consistency in each standard size of core.

Deltamax is the most recent extension of the family of special, high-quality electrical materials produced by Allegheny Ludlum, steel-makers to the electrical industry. It is an orientated 50% nickel-iron alloy, characterized by a rectangular hysteresis loop with sharply defined knees, combining high saturation with low coercivity.

● *Call on us for technical data.*

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

147 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS

W&D 2379

The NEW LAVOIE LA-239A VIDEO OSCILLOSCOPE Gives Quantitative Data (Amplitude and Time) In ONE Instrument.

● EASY OPERATION
● EASY MOBILITY

SINE WAVES OBSERVABLE
10 cycles to 5 megacyles per second

TRANSIENTS OBSERVABLE
Mimimum rise time—0.08 microsecond (10% to 90%)
Maximum square-pulse duration
5,000 microseconds

SIGNAL INPUT IMPEDANCE
Oscilloscope alone—300,000 ohms paralleled by 30 mmf.
Oscilloscope with probe—3 megohms paralleled by 12 mmf.

SYNCHRONIZING INPUT IMPEDANCE
Oscilloscope alone—300,000 ohms paralleled by 30 mmf.
Oscilloscope with probe—3 megohms paralleled by 12 mmf.

SIGNAL INPUT VOLTAGE AND SENSITIVITY, NOMINAL FOR IMAGE OF STANDARD AMPLITUDE 0. 6 INCH
Oscilloscope alone—0.1 to 100 volts, peak
With probe—Ten times voltage with oscilloscope alone with maximum limit of 450 volts, peak.

SWEEP TIME
0.5 to 50,000 microseconds per inch, continuous.

SWEEP CIRCUIT
Start-stop, each sweep independent of preceding.

SYNCHRONIZING MEANS AND VOLTAGE
Internal—Leading or lagging edge of pulse. Signal under observation or trigger generator.
External—Without probe—± 0.5 to ± 150 volts, peak.
With probe—± 5 to ± 450 volts, peak.

● *Write for quotation and any additional information*

CALIBRATING VOLTAGE
An internally generated square wave of approximately 150 cycles per second, adjustable from 0.1 to 1 volt peak-to-peak and applied directly to the input of the signal amplifiers, which follow the multiplier. A 75 volt square wave for calibrating vertical plate deflections, etc.

TIMING MARKERS
Synchronized with sweep and available at intervals of 0.2, 1, 10, 100 or 500 microseconds.

TRIGGER PULSE OUTPUT
± 25 volts, 4 microsecond pulses, occurring at 300, 800, 2,000 or 5,000 pps. and with rise time of ½ microsecond

SWEEP DELAY AND EXPANSION
Any portion of sweeps nominally over 10 microseconds may be delayed and expanded about 10 times for detailed examination of signal.

MEASURING SCALE
30 x 40 divisions, illuminated, optically produced, free from parallax and visible only when wanted, with any desired brightness.

EXTERNAL CONNECTIONS AVAILABLE
To vertical plate of cathode-ray tube. (Maximum peak voltage, 450)
Through 100,000 micromicrofarads with sensitivity of approximately 110 volts per inch deflection.
To horizontal amplifier. (Maximum peak voltage, 450)
Through potentiometer allowing sensitivity to be varied from approximately 8 to 200 volts per inch deflection. Band width 10 to 10,000 cycles.

TO CATHODE OF CATHODE-RAY TUBE (Z AXIS)
Through 10,000 micromicrofarads. Internal timing markers cannot be used simultaneously.

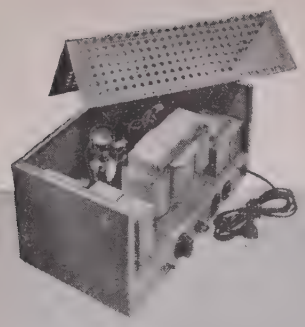
CATHODE-RAY TUBE—3JP1

POWER SUPPLY
Volts 115—50 to 1,600 cycles per second.

Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS
MORGANVILLE, N. J.

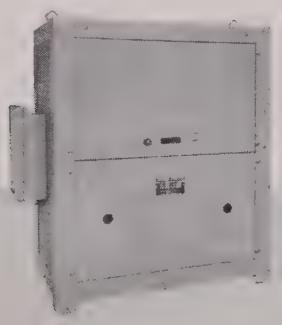
Specialists in the Development and Manufacture of UHF Equipment



General Application

Model	Load Range Volt-Amperes	*Regulation Accuracy
150	25-150	0.5%
250	25-250	0.2%
500	50-500	0.5%
1000	100-1000	0.2%
2000	200-2000	0.2%

*Models available with increased regulation accuracy.



Extra Heavy Loads

Model	Load Range Volt-Amperes	*Regulation Accuracy
3,000	300-3000	0.2%
5,000	500-5000	0.5%
10,000	1000-10,000	0.5%
15,000	1500-15,000	0.5%

*Models available with increased regulation accuracy.

the first line of STANDARD electronic AC voltage regulators and nobatrons

GENERAL SPECIFICATIONS

- Harmonic distortion : max. 5% basic or 2% "S" models
- Input voltage range: either 95-125 or 190-250 volts
- Output: adiustable between either 110-120 or 220-240 volts
- Input frequency range: 50-60 cycles
- Power factor range: down to 0.7 P. F.

All AC Regulators and Nobatrons may be used at no load.

Special Models designed to meet your unusual applications.

Write for the new Sorensen catalogue. It contains complete specifications on standard Voltage Regulators and Nobatrons.

Special Transformers, D. C. Power Supplies, Saturable Core Reactors and Meter Calibrators made to order; please request information.

SORENSEN & Company, Inc.

Stamford, Connecticut

Represented in all principal cities.

The NOBATRON Line

Output Voltage DC	Load Range Amps.
6	5-15-40-100
12	5-15-50
28	10-30
48	15
125	5-10

Regulation Accuracy—.25% from ¼ to full load.

400 Cycle Line

Inverter and Generator Regulators for Aircraft

Single Phase and Three Phase

Model	Load Range Volt-Amps.	Reg. Accuracy
D 100	10-100	0.5%
D 500	50-500	0.5%
D 1200	120-1200	0.5%
D 2000	200-2000	0.5%

3-Phase Regulation

Star-connected three-phase systems can be handled effectively. Other three-phase systems must be reviewed by our Engineering Dept. VA Capacities up to 45 KVA.

FREED

"PRODUCTS of EXTENSIVE RESEARCH"

INSTRUMENTS & COMPONENTS!

HIGH FIDELITY OUTPUT TRANSFORMERS

Type No.	Primary matches following tubes	Primary impedance	Secondary impedance	DCMA	Max. power rating
F-952	Push Pull 2A3's, 6A5G's, 300A's	5000 ohms	500, 333, 250, 200, 15, 10	25-30000 cycles	5 watts
F-95	Push Pull 2A3's, 6A5G's, 300A's	5000 ohms	20, 15, 10, 8, 5, 4, 3, 2	25-30000 cycles	5 watts
F-954	Push Pull 2A5, 25L6, 42's or 2A5 A primes	8000 ohms	500, 333, 250, 200, 15, 10	25-30000 cycles	5 watts
F-955	Push Pull 2A5, 25L6, 42's or 2A5 A primes	8000 ohms	20, 15, 10, 8, 5, 4, 3, 2	25-30000 cycles	5 watts
F-956	Push Pull 6B5, 6A3, 53, 6F6, 59, 79, 89, 6A3's, Class B 46's	10000 ohms	625, 500, 350, 250, 15, 10	25-30000 cycles	5 watts
F-957	Push Pull 6B5, 6A3, 53, 6F6, 59, 79, 89, 6A3's, Class B 46's	10000 ohms	25, 20, 15, 10, 8, 5, 4, 3, 2	25-30000 cycles	5 watts
F-962	Push Pull, Parallel 2A3's, 6A5G's, 300A's, 6A3's, 46's	2500 ohms	125, 100, 75, 50, 15, 10	25-30000 cycles	30 watts
F-963	Push Pull, parallel 2A3's, 6A5G's, 300A's, 6A3's, 46's	2500 ohms	20, 15, 10, 8, 5, 4, 3, 2	25-30000 cycles	30 watts
F-966	Push Pull 46's or Push Pull 2A3's or 6A3's	3800 ohms	500, 333, 250, 200, 15, 10	25-30000 cycles	50 watts
F-967	Push Pull 46's or Push Pull 2A3's or 6A3's	3800 ohms	20, 15, 10, 8, 5, 4, 3, 2	25-30000 cycles	50 watts

"Q" INDICATOR

No. 1030 Frequency range from 20 cycles to 50 kilocycles. "Q" range from .5 to 500. "Q" of inductors can be measured with up to 50 volts across the coil. Indispensable instrument for measurement of "Q" and inductance of coils, "Q" and capacitance of capacitors, dialectric losses, and power factor of insulating materials.

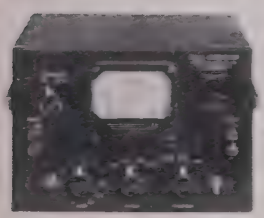
INCREMENTAL INDUCTANCE BRIDGE

IMPEDANCE RANGE: One millihenry to 1000 henries in five ranges. Inductance values are read directly from a four dial decade and multiplier switch. This range can be extended to 10,000 henries by the use of an external resistance

INDUCTANCE ACCURACY: Within plus or minus 1% through the frequency range from 60 to 1000 cycles.

COMPARISON BRIDGE

No. 1010 An invaluable instrument for precision laboratory adjustment and incoming inspection of resistors, capacitators and inductors . . . Entirely self-contained, A.C. operated and includes a three frequency oscillator, an A.C. bridge and a null detector.



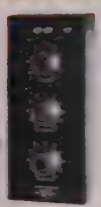
NULL DETECTOR

No. 1140 For bridge measurements, providing visual null indications or aural indications when used in conjunction with headphones. The unit may also be used as a high gain amplifier for general laboratory work. Functionally, the instrument consists of a high gain linear amplifier with a 30 db input attenuator in addition to the variable gain control. Output voltage is 40 volts undistorted into 1 megohm load, and 10 volts into 20,000 ohms.

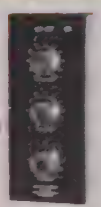
HERMETICALLY SEALED *COMPONENTS*

Decade Inductors

No. 1160
10 x 1 MY steps
10 x .1 MY steps
10 x .01 MY steps
500 15,000 cycles



No. 1161
10 x .1 MY steps
10 x .01 MY steps
10 x .001 MY steps
2000 50,000 cycles



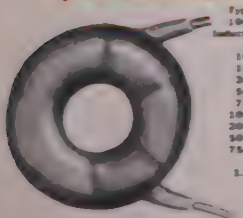
No. 1162
10 x .01 MY steps
10 x .001 MY steps
10 x .0001 MY steps
10,000 300,000 cycles

No. 1164
10 x 10 MY steps
10 x 1 MY steps
10 x .1 MY steps
50 1000 cycles

Discriminators

For telemetering and remote control applications using audio and supersonic frequency subcarriers.

Toroidal Inductors



Type T1 1000-15,000 cycles		Type T1-2 2000-30,000 cycles		Type T1-3 10,000-300,000 cycles	
Inductance Value	Type #	Inductance Value	Type #	Inductance Value	Type #
5 MHY	F-8007T	1 MH	F-1800	.5 MH	F-1850
10 MHY	F-8011T	2 MH	F-1801	1 MH	F-1851
15 MHY	F-8021T	3 MH	F-1802	2 MH	F-1852
20 MHY	F-8031T	4 MH	F-1803	3 MH	F-1853
50 MHY	F-8041T	5 MH	F-1804	4 MH	F-1854
75 MHY	F-8051T	10 MH	F-1805	5 MH	F-1855
100 MHY	F-8061T	15 MH	F-1806	10 MH	F-1856
200 MHY	F-8071T	20 MH	F-1807	15 MH	F-1857
500 MHY	F-8081T	50 MH	F-1808	20 MH	F-1858
750 MHY	F-8101T	75 MH	F-1809	30 MH	F-1859
1 MY	F-8111T	100 MH	F-1810	40 MH	F-1860
1.5 MY	F-8121T	150 MH	F-1811	50 MH	F-1861
2 MY	F-8131T	200 MH	F-1812	75 MH	F-1862
3 MY	F-8141T	300 MH	F-1813	100 MH	F-1863
4 MY	F-8211T	400 MH	F-1814		
5 MY	F-8231T	500 MH	F-1815		

High quality toroidal coils wound on molybdenum permalloy dust cores. All those listed above can be supplied in hermetically sealed cans, commercial type construction or open units. Other types can be supplied out of stock on special orders.

LOW FREQUENCY HI "Q" COILS

#1900	100 HY
#1901	75 HY
#1902	50 HY
#1903	25 HY
#1904	10 HY
#1905	5 HY
#1906	1 HY

Available from stock in the indicated inductance values.

Filters

Narrow band pass filters for remote control and telemetering applications. High pass, low pass, band pass and band elimination filters for communication and carrier systems.

SEND FOR COMPLETE DESCRIPTIVE LITERATURE

FREED TRANSFORMER CO., Inc.

DEPT. PJ 1718-36 WEIRFIELD ST., (RIDGEWOOD) BROOKLYN 27, NEW YORK

Everything IN CARBON *but Diamonds!*

PLUS GRAPHITE, MOLDED METALS SINTERED ALNICO II

HUNDREDS of STANDARD ITEMS . . . *thousands of "Specials"*

Write for details on any type

Anodes • Battery Carbons
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Brazing Furnace Boats
Brushes of all types for rotating electrical equipment
Carbon and Graphite Contacts
Chemical Carbons • Clutch Rings
Dash Pot Plungers
Electric Furnace Heating Elements
Electrolytic Anodes • Friction Segments
Glass Molds • Ground Rods (carbon)
Mercury Arc Rectifier Anodes
Metal-Graphite Contacts
Power Tube Anodes
Rail Bonding Molds
Rare Metal Contacts
Resistance Welding and Brazing Tips
Seal Rings (for gas or liquid)
Special Molds and Dies
Spectrographite No. 1
Trolley and Pantograph Shoes
Voltage Regulator Discs
Water Heater and Pasteurization Electrodes
Welding Carbons
Welding Plates and Paste

. . a dependable source of supply

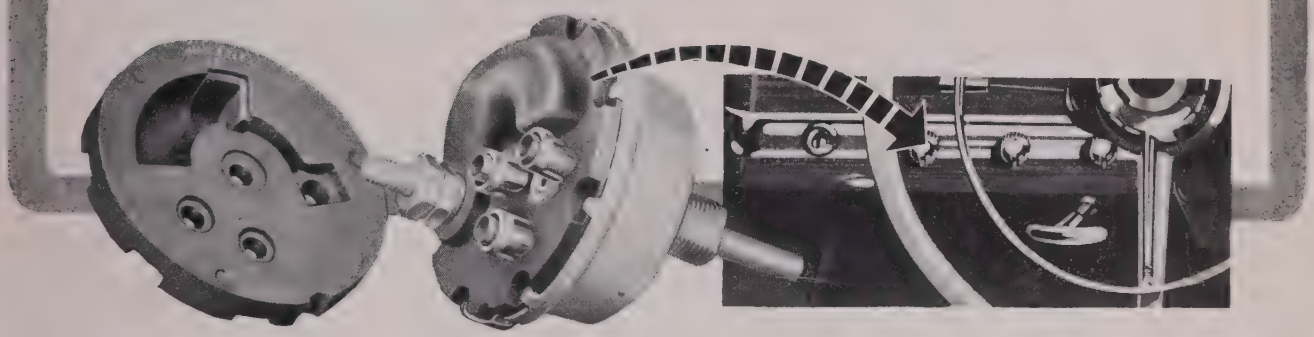
The unique electrical, mechanical, physical and chemical properties of Stackpole carbon, graphite and carbon-graphite products solve countless problems of friction, temperature, arcing, corrosion, shaft sealing, voltage regulating and others. So broad is the line of standard Stackpole products, so extensive the facilities for "specials" that it is practical to list only a few of them here. Let Stackpole engineers recommend and quote on your next requirements.

STACKPOLE

STACKPOLE CARBON CO., ST MARYS, PA.

ONCE AGAIN, MYCALEX 410 GETS THE CALL . . .

Leading Automobile firm specifies MYCALEX 410 molded insulation for new dashboard lightswitch . . .



Sorry, we can't mention names, but this is the insulator body for a new type of dash-board light-switch being manufactured of MYCALEX 410 molded insulation for one of the leading lines of cars*. . .*names on request.

It's no great secret that automotive firms buy wisely and well . . . and it's justly proud we are that after making exhaustive tests and comparisons, this large maker of cars specified MYCALEX 410 molded insulation as ideal for the new type dash-board light-switch being introduced in their 1949 line.

Again, it was proved that on long run, round the clock production, MYCALEX 410 insulation parts, molded with or without metal inserts, are low-cost and competitive with less-effective molded insulation materials.

Again, MYCALEX 410 molded insulation demonstrated its absolute dimensional and electrical stability; low dielectric loss; high dielectric strength; high arc resistance; stability over wide humidity and temperature changes; resistance to high temperatures, moisture and oils; and great mechanical precision and strength. Inserts of common or precious metals may be injected in the MYCALEX 410 molding process.

Yes, MYCALEX 410 molded insulation meets the most exacting requirements of high frequency applications.

REMEMBER . . .

MYCALEX 410 MOLDED INSULATION IS THE EXCLUSIVE FORMULATION OF MYCALEX CORPORATION OF AMERICA.

We stock these
MYCALEX 410
Tiny Tie-In Terminals
for . . .
Sub-miniature
Transmitting Equipment

SINCE 1919 MYCALEX THE INSULATOR

MYCALEX CORP. OF AMERICA

"Owners of 'MYCALEX' Patents"

Plant and General Offices, CLIFTON, N. J. *Executive Offices,* 30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

World's Tallest Radio Towers
designed and engineered by Truscon

• Never before has man reached so high into the sky with ground-supported radio towers. Never before have man's skill and science achieved such a structural masterpiece for transmitting sound.

These new 1220-foot Truscon Radio Towers are an outstanding development. Truscon engineers had to meet many essential requirements and specifications never before encountered in structures of this type.

More TRUSCON TOWERS OF STRENGTH 1220 FT. HIGH

Broadcasters the world over depend on Truscon Radio Towers for maintenance of continued schedules to hold listeners. Every Truscon tower is *engineered to its location*...windy or sheltered... open or mountainous... humid or dry. And, each is a product of the finest materials and workmanship serving your industry.

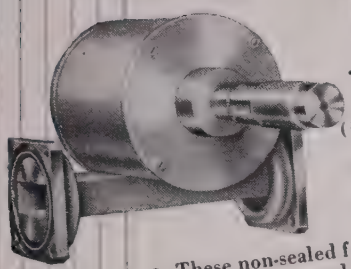
Truscon can design and erect exactly the tower you need...tall or small...guyed or self-supporting... uniform or tapered in cross-section..for AM, FM and TV. For engineering assistance without obligation, phone or write our home office in Youngstown, O., or any convenient Truscon district office.

TRUSCON STEEL COMPANY
YOUNGSTOWN 1, OHIO
Subsidiary of Republic Steel Corporation

TRUSCON TOWERS
SELF-SUPPORTING AND UNIFORM CROSS SECTION GUYED

PRD

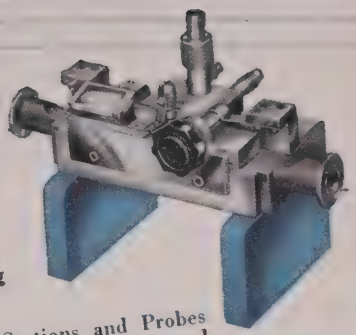
MICROWAVE MEASUREMENT COMPONENTS Now Available..



TYPE 551-A—REACTION TYPE FREQUENCY METER
(1" x ½" waveguide)

High Q cavity; Precise and permanent calibration; Extraneous mode suppression

● These non-sealed frequency meters will soon be augmented by a new line of hermetically sealed, temperature compensated units covering the frequency range from 500 to 40,000 megacycles per second. Also available: frequency standarized signal sources.

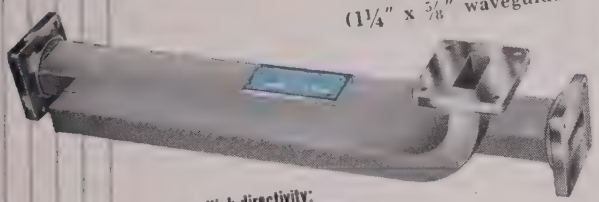


TYPE 211—PRECISION WAVEGUIDE SLOTTED SECTION
(0.420" x 0.170" I.D.)

Broadband operation; Crystal and bolometer detection; Ball bearing carriage support

● Similar Slotted Sections and Probes in standard rectangular waveguide and coaxial line sizes make possible precise impedance measurements over the microwave spectrum from 1000 to 40,000 megacycles per second.

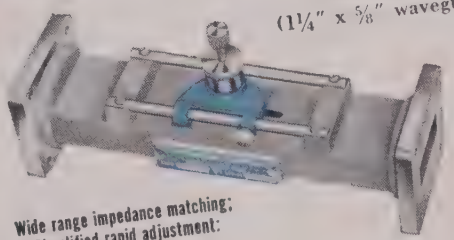
TYPE 401—DIRECTIONAL COUPLER
(1¼" x ⅝" waveguide)



High directivity; Minimum frequency sensitivity; Broadband operation

● This unit is representative of a group of mono-directional broadband couplers covering in four waveguide sizes the frequency range from 4000 to 10,000 megacycles per second.

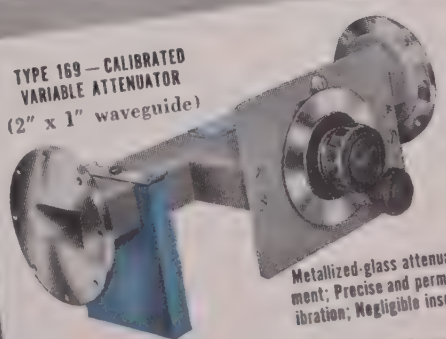
TYPE 302—SLIDE SCREW TUNER
(1¼" x ⅝" waveguide)



Wide range impedance matching; Simplified rapid adjustment; Broadband operation

● Also available: similar units in standard waveguide sizes, fixed and tunable crystal and bolometer mounts, dielectric tuning devices for coaxial lines.

TYPE 169—CALIBRATED VARIABLE ATTENUATOR
(2" x 1" waveguide)



Metallized-glass attenuating element; Precise and permanent calibration; Negligible insertion loss

● A full complement of fixed and variable attenuators and broadband terminations in standard waveguide sizes provides coverage for the frequency range from 2600 to 40,000 megacycles per second. Fixed pads and terminations are available for standard coaxial transmission lines.

The items presented above are representative of the complete PRD line of precision microwave measurement and test equipment. These units embody basically new design principles calculated to provide the microwave research engineer with the ultimate in accuracy and reliability. A skilled staff of engineers and physicists is constantly pioneering the advance to the higher frequency regions of the microwave spectrum and stands ready to assist in the solution of your microwave problems. An illustrated catalog may be obtained by writing on company letterhead to Dept. R-3.

P R D

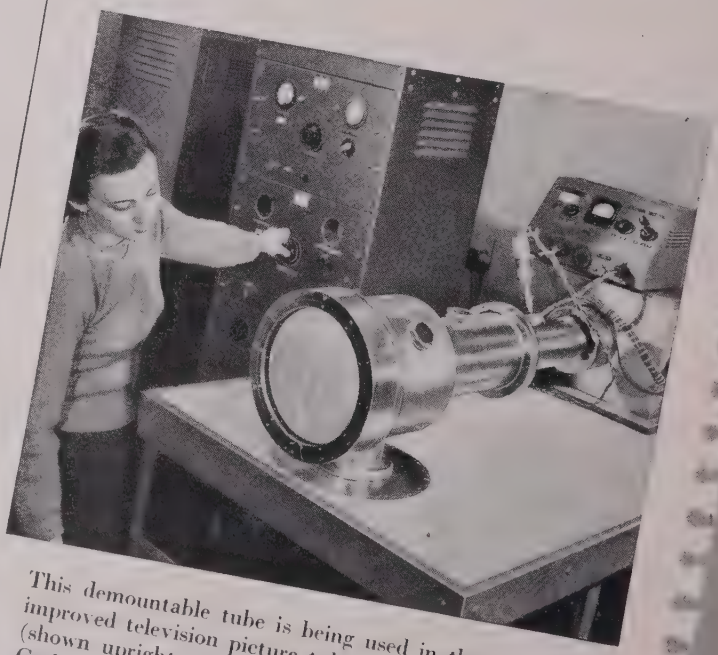
Polytechnic **RESEARCH & DEVELOPMENT COMPANY, Inc.**

202 TILLARY ST., BROOKLYN 1, N. Y.

A page from the note-book of Sylvania Research

The Demountable Cathode Ray Tube for the continuous improvement of television picture tube reception!

DESIGNED by Sylvania physicists, the Demountable Cathode Ray Tube allows experimental checking of theoretical design of electron optical systems. It is made so that various component parts of television picture tubes may be redesigned and fitted into the system for continuing research. Used in conjunction with Sylvania's Electrolytic Tank that enables engineers to make meticulous studies of the behavior of electrons in electron optical systems, this metal demountable tube is another example of never-ending Sylvania efforts for finer and finer products. Sylvania Electric Products Inc., 500 Fifth Avenue, New York 18, N. Y.

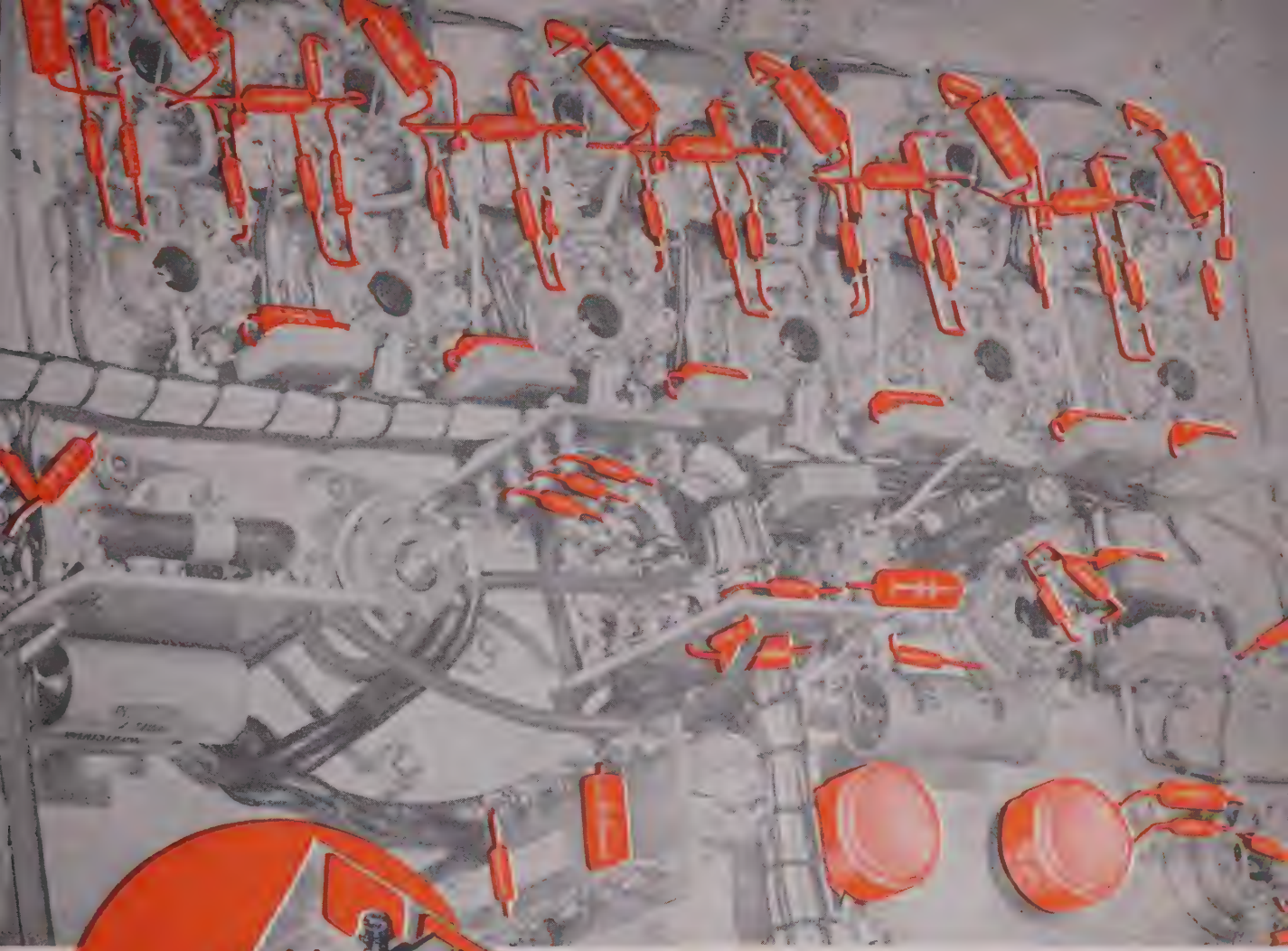


This demountable tube is being used in the design of improved television picture tubes. An ionization gauge (shown upright at the small end of the Demountable Cathode Ray Tube) affords accurate control of the degree of vacuum in the system...while precision power supply is obtained from the unit shown in the background being used by the physicist.

★ ★ ★

SYLVANIA ELECTRIC

ELECTRONIC DEVICES; RADIO TUBES; CATHODE RAY TUBES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES, SIGN TUBING; LIGHT BULBS; PHOTOLAMPS



Scaler made by Nuclear Instrument & Chemical Corporation, Chicago, Illinois.

103 Bradleyunits in NI & C Scaler.

Two Bradleyometers in the Scaler.

105 ALLEN-BRADLEY FIXED AND ADJUSTABLE RESISTORS

in this automatic scaling unit

"Our Model 163 Automatic Scaling Unit," says John L. Kuranz, of Nuclear Instrument & Chemical Corporation, Chicago, "contains 103 Allen-Bradley fixed resistors and two Bradleyometers. To achieve the dependability so necessary in this type of research tool, our tests show that only A-B resistors can be used. In addition to their functional superiority, their small size makes our portable instruments really portable."

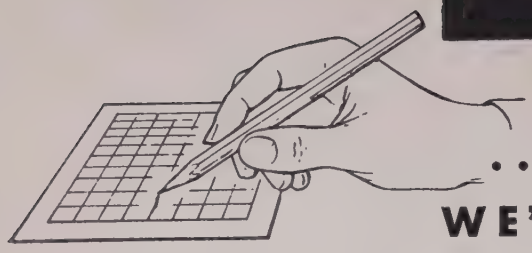
Where superlative performance is a *must* . . . where unfailing dependability is a basic requirement . . . as in nuclear research . . . you will find Allen-Bradley quality resistors. If you *must* meet high-quality standards . . . specify Allen-Bradley resistors.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis.

ALLEN-BRADLEY RADIO RESISTORS

QUALITY

FONO-FITTED TORQUE ℰV DRIVE CARTRIDGES



...you draw the curve

WE'LL BUILD THE CARTRIDGE

*Your specifications . . . your special requirements in phono pickup cartridges . . . are ideally "custom-solved" through E-V creative engineering . . . unusual manufacturing facilities . . . and inherent advantages of exclusive TORQUE DRIVE.**

CUSTOM RESPONSE

Smooth upper response with roll off frequency to your specifications or wide range, peak-free response to 10 kc. You draw the curve, we'll build the cartridge.

VOLTAGE

E-V TORQUE DRIVE cartridges provide the highest compliance per volt output. For example, the E-V 14 cartridge tracks at 5 grams with excellent wave form down through 50 c.p.s. on the RCA 12-5-31V record at 1 volt at 1,000 c.p.s.

TRACKING FORCE

With the high compliance and low mass of the driving system, needle forces at 5 grams for both one and three mil records are used in everyday production by leading manufacturers. Cartridges with even lower needle force with slight reduction in voltage are thoroughly practical. 3 gram tracking pressures are definitely in sight.

COMBINATION
One and Three Mil

E-V TORQUE DRIVE again leads in twin needle cartridge design. Tracking force of 5 grams on both one and three mil records precludes weight changing. Straight line needle position assures accurate set down when used with changers. Approximately the same output is obtained on both stylii. The E-V Twin-Tilt cartridge mounts in any arm with ½" mounting holes with no modification except adjustment for correct needle force.

MOISTURE PROOFING

The cartridge is *entirely filled* with DC4 Silicone jelly—the material that is used for inhibiting moisture on aircraft wiring. Tests indicate that it increases the life of an ordinary crystal *some 20 times.* This is a *plus* feature, found in all E-V crystal cartridges.

Our engineering staff and full facilities are at your service. Contact us today.

Modern One-Acre Plant with Complete Internal Facilities for Quality-Controlled Volume Production

From original conception to final product, you get full benefit of the unusual E-V processes. Here are E-V laboratories, where constant research keeps making new contributions to the Art. Here we make tools and dies . . . die cast, plate, screw machine, stamp, mold plastics, and assemble. Here we use specially designed test equipment for quality control. With all these facilities, we produce high standard acoustical products in quantity, with utmost economy. Come—see this plant in action.

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FIRST CHOICE OF BRANIFF *International* AIRWAYS

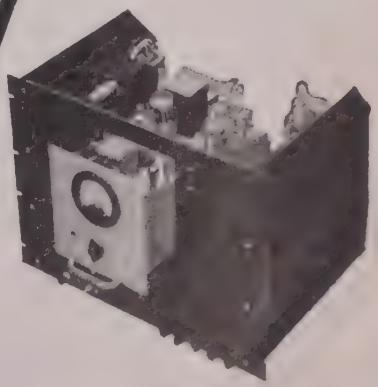
BRANIFF EQUIPS GROUND STATIONS WITH WILCOX TYPE 364A TRANSMITTER

DESIGN SIMPLIFIES SERVICE
Conventional circuit design, fewer numbers and types of tubes, plus open mechanical construction simplify tube stocking problems and speed maintenance. The entire transmitter portion of the Type 364A is built on a drawer-type chassis, instantly withdrawable from the front of the panel.

RELAY RACK MOUNTING SAVES SPACE
Compact design requires only 15 inches of rack space for installation, frequently utilizing space already available.

.005% FREQUENCY STABILITY WITHOUT TEMPERATURE CONTROL
Through the use of a newly developed crystal, troublesome thermostatic temperature controls and crystal ovens are no longer necessary to provide adequate frequency stability.

SIMPLIFIED CONTROL FOR REMOTE LOCATION
Modulation over a single telephone pair and carrier control by means of a simplex circuit allow the transmitter to be readily located at a remote point.



WILCOX
Type 364A Transmitter
118-136 MC. Band

WILCOX
ELECTRIC COMPANY
KANSAS CITY 1, MISSOURI

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Complete Information

THE FOUNTAINHEAD OF MODERN TUBE DEVELOPMENT IS RCA

RCA SPECIAL RED TUBES

Minimum life—10,000 hours!

● *Another RCA First* . . . these new Special Red Tubes are specifically designed for those industrial and commercial applications using small-type tubes but having rigid requirements for reliability and long tube life.

As contrasted with their receiving-tube counterparts, RCA Special Red Tubes feature vastly improved life, stability, uniformity, and resistance to vibration and impact. Their unique structural design makes them capable of withstanding shocks of 100 g for extended periods. Rigid processing and inspection controls provide these tubes with a minimum life of 10,000 hours when they are operated within their specified ratings. Extreme care in manufacturing combined with precision designs account for their unusually close electrical tolerances.

RCA Application Engineers will be pleased to co-operate with you in adapting RCA Special Red Tubes to your equipment. Write RCA Commercial Engineering, Section 47FR, Harrison, N. J. For RCA Special Red Tubes to be used as replacements in equipment now in use, see your local RCA TUBE DISTRIBUTOR.

TABLE OF RECEIVING-TYPE COUNTERPARTS

5691 (0.6 A. heater)	6SL7GT (0.3 A. heater)
5692	6SN7GT
5693	6SJ7

RCA Special Red Tubes can be used as replacements for their counterparts in equipment where long life, rigid construction, extreme uniformity, and exceptional stability are needed.

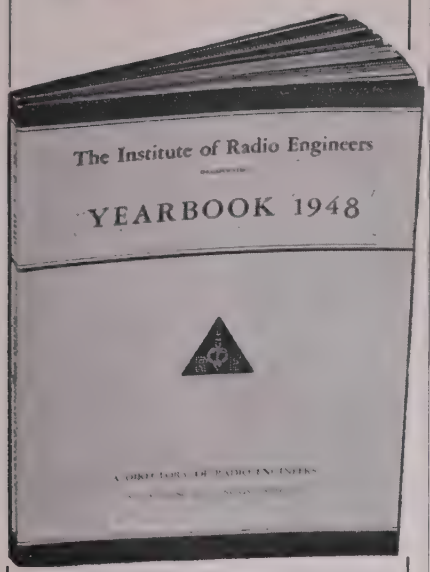
SEND FOR FREE BULLETIN—Booklet SRB-1002 provides complete data on RCA Special Red Tubes. For your copy write to RCA, Commercial Engineering, Section 47FR, Harrison, N.J.

TUBE DEPARTMENT

RADIO CORPORATION of AMERICA

HARRISON, N. J.

COMING



1949 Edition

It Publishes

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- Biographies of Fellows
- Constitution of I R E and Secretary's Report

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Now—reduce inventory problems, improve deliveries, maintain your quality—specify KENYON "T's," the finest transformer line for all high quality equipment applications.

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KENYON new modified edition tells the complete story about specific ratings on all transformers. Our standard line saves you time and expense. Send for your copy of our latest catalog edition *now!*

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S·S·White MOLDED RESISTORS

The "All-Weather" Resistors

ARE USED IN THIS HIGH-SPEED GEIGER-MULLER COUNTER

They're used in the quenching circuit. El-Tronics, Inc., Philadelphia, Pa. the manufacturer says—"We have been using and will continue to use S.S.White Resistors since we find them extremely satisfactory and most compact of all types available."

Photo courtesy of El-Tronics, Inc. Philadelphia, Pa.

S.S.WHITE RESISTORS
are of particular interest to all who need resistors with inherent **low noise level** and **good stability** in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS

STANDARD RANGE
1000 OHMS TO
9 MEGOHMS

WRITE FOR BULLETIN 4505

It will give you full details about S.S.White Resistors including construction, characteristics, dimensions, etc. A copy, with Price List, will be mailed at your request.

S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO.
DEPT. GR, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AND ACCESSORIES
MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

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INTERNATIONAL
TELEVISION

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life-size more life-like television

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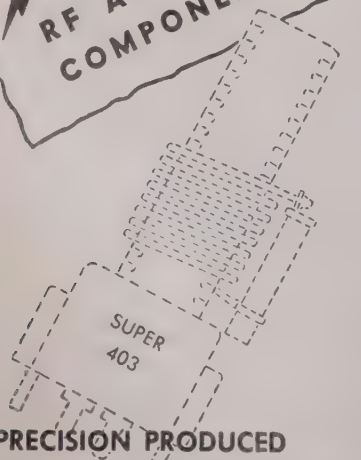

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● PERFORMANCE PROVED

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CANOGA CORPORATION
Announces
IT'S MODEL 708
SPECTRUM ANALYZER
FOR X BAND
EQUIVALENT TO RAD LAB
MODEL 105
IN PERFORMANCE
And also
MODEL 705
WOBBULATOR
SIGNAL GENERATOR
2 TO 500 M.C.
EQUIVALENT TO RAD LAB
MODEL 738
FOR INFORMATION WRITE
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P.O. BOX 361
VAN NUYS, CALIFORNIA

Urgently Need

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Found
at the
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March 7-10, New York
A small camera.
Send description to
J. Robert Marcett
IRE
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Student Branch Meetings 38A
Membership 42A
Positions Open 50A
Positions Wanted 52A

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Arnold Engineering Co. 16A
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Centralab. . . . . 14A & 15A, 39A
Cleveland Container Co. 41A
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Electro-Motive Mfg. Co., Inc. ... 7A
Electro-Voice, Inc. 30A
Electronic Engineering Co. of Calif. 62A
Electro Search 63A

W. L. Foss 63A
Freed Radio Co. 53A
Freed Transformer Co., Inc. 21A
Furst Electronics 58A

General Electric Co. 1A, 10A, 11A, 25A
General Radio Co. ..... Cover IV
Paul Godley 63A
H. L. Gordon 63A
Samuel Gubin 63A

Hazeltine Electronics Corp. 50A
Hewlett-Packard Co. 3A

International Nickel Co. 33A

E. F. Johnson Co. 59A

Kenyon Transformer Co., Inc. 61A
James Knights Co. 60A

Lambda Electronics Corp. 53A
James B. Lansing Sound Inc. 46A
Lavoie Labs. 19A

P. R. Mallory & Co., Inc. 6A
Measurements Corp. 60A
Melpar, Inc. 50A
Murray Hill Books, Inc. 46A
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National Union Radio Corp. 50A
New York Transformer Co. 47A
J. M. Ney Co. 57A
North American Philips Co. 62A

Ohmite Mfg. Co. 9A

Panoramic Radio Corp. 53A
Polytechnic Research & Dev. Co. 27A

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Radio Corp. of America 32A, 51A, 64A
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Sorensen & Co. 20A
Spencer-Kennedy Laboratories, Inc. 56A
Sperry Gyroscope Co. 51A
Sprague Electric Co. 2A
Stackpole Carbon Co. 22A
Super Electric Products Corp. ... 62A
Sylvania Electric Products Co., Inc. 28A

Technical Materiel Corp. 63A
Technology Instrument Corp. 42A, 57A
Television Equipment Corp. 51A
Transradio Ltd. 58A
Truscon Steel Co. 24A

United Transformer Co. ..... Cover II

Webster Electric Co. 38A
S. S. White Dental Mfg. Co. 49A, 61A
Wilcox Electric Co. 31A
John Wiley & Sons, Inc. 42A, 44A
Westinghouse Electric Corp. 52A

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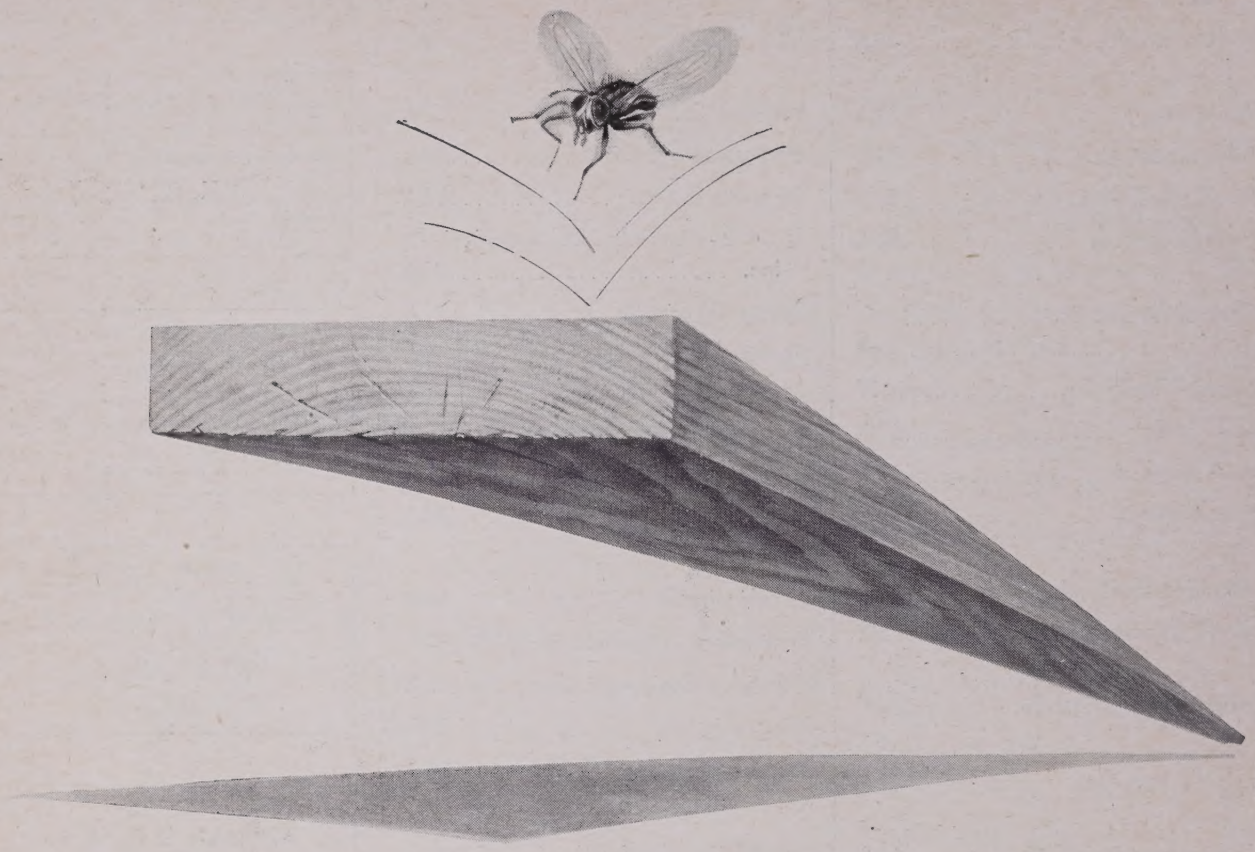

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Surprising though it seems, a fly—when it lands on a board—causes distinct vibrations. They can be detected by a remarkable new RCA electron tube.

Slimmer than a cigarette, and only half as long, RCA's tube picks up vibrations with a pin-sized shaft—and these vibrations may then be converted to visible or audible signals. More important, the new tube can be used to make measurements of the degree of vibration.

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A midget-sized gargantua . . . a powerhouse of a capacitor that's armored to take all the stress and strain, vibration, humidity and extremes of temperature that comes its way. If the paper tubulars you're now using lack any of these 8 strong points, you're being short-changed. Switch to C-D BLACK CUBS as other leading manufacturers have done!

1. "LEADWELD" CONNECTIONS! Sturdy welded joints between wire leads and foil of capacitor section. Permanent connections! No intermittents! No open circuit defects!

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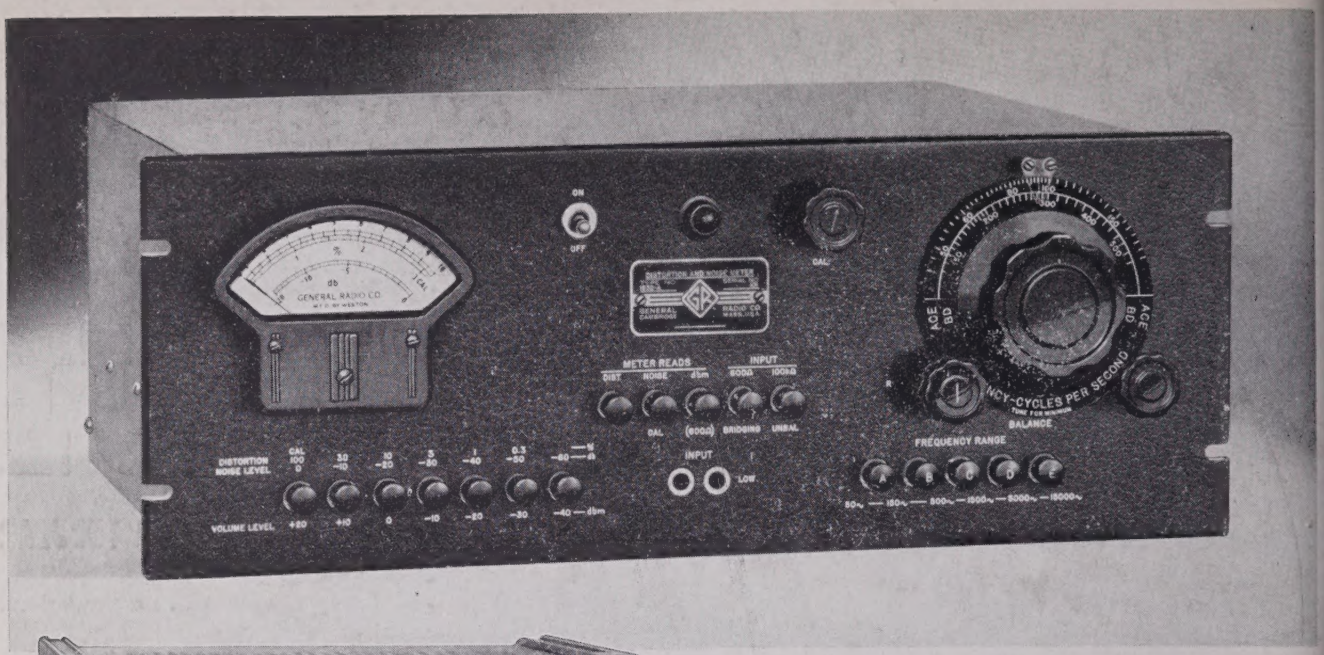


Type 1301-A Low-Distortion Oscillator

Here's Your "PROOF-OF-PERFORMANCE"

AS ANNOUNCED by the Federal Communications Commission,* effective August 1, 1949 all a-m and f-m broadcast stations will be required to make proof-of-performance checks of over-all noise and distortion of the complete station at least once a year.

Many stations already make these measurements at frequent intervals as routine operating maintenance to insure the continuous high-quality service the modern transmitter system is capable of supplying.

General Radio instruments for these measurements have been available for some time, and are in regular use by the leading stations where this equipment has given accurate, convenient-to-use and trouble-free service.

The G-R Type 1932-A Distortion and Noise Meter meets all of the F.C.C.'s requirements for measurements of this type for both a-m and f-m services; the Type 1301-A Low-Distortion Oscillator is the ideal companion unit for use with the Type 1932-A. Both of these instruments are relay-rack mounted and can be supplied in panel finishes to match most existing installations.

TYPE 1932-A DISTORTION & NOISE METER

For measurements of sine-wave voltages, distortion and noise throughout the audio range. Over-all pass-band of the voltmeter circuit extends to 45,000 cycles, thus including all noise and distortion products contained in this range; particularly the 3rd harmonic of a 15,000-cycle test is included.

This instrument is continuously adjustable and can be set to any frequency quickly since it has only one main tuning control plus a small trimmer. With it measurements can be made on a-f distortion in radio transmitters, line amplifiers, speech amplifiers, speech input equipment to lines; noise and hum levels of a-f amplifiers, wire lines to the transmitter, remote pick-up lines and other station equipment.

Full-scale deflections on the large meter read distortions of 0.3, 1, 3, 10 or 30 per cent; range for carrier noise measurements extends to 80 db below 100% modulation, or 80 db below an a-f signal of zero dbm level. The a-f range is 50 to 15,000 cycles, fundamental, for distortion measurements and 30 to 45,000 cycles for noise and hum.

Type 1932-A Distortion and Noise Meter: **$575.00**

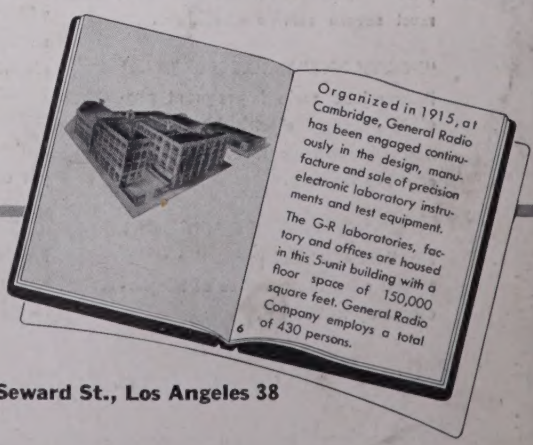
TYPE 1301-A LOW-DISTORTION OSCILLATOR

Especially designed for rapid measurements, this highly-stable oscillator has exceptionally low distortion. By means of push buttons, 27 fixed frequencies between 20 and 15,000 cycles may be selected in logarithmic steps. Any frequency between steps can be obtained by plugging in external resistors. The distortion over the entire range will not exceed the following percentages: with 5,000-ohm output, 0.1% from 40 to 7,500 cycles; 0.15% at other frequencies. With 600-ohm output 0.1% from 40 to 7,500 cycles; 0.25% from 20 to 40 cycles and 0.15% above 7,500 cycles.

The oscillator is calibrated to within $\pm(1\frac{1}{2}\% + 0.1$ cycle); the calibration is not affected by changes in load or plate supply voltage; drift is less than 0.02% per hour after a few minutes operation. The operation of the oscillator is unaffected by ordinary climatic changes.

Type 1301-A Low Distortion Oscillator: **$395.00**

*F.C.C. Rules and Regulations, Sections 3.254 and 3.46, as amended


Organized in 1915, at Cambridge, General Radio has been engaged continuously in the design, manufacture and sale of precision electronic laboratory instruments and test equipment.
The G-R laboratories, factory and offices are housed in this 5-unit building with a floor space of 150,000 square feet. General Radio Company employs a total of 430 persons.
6

GENERAL RADIO COMPANY

Cambridge 39, Massachusetts

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